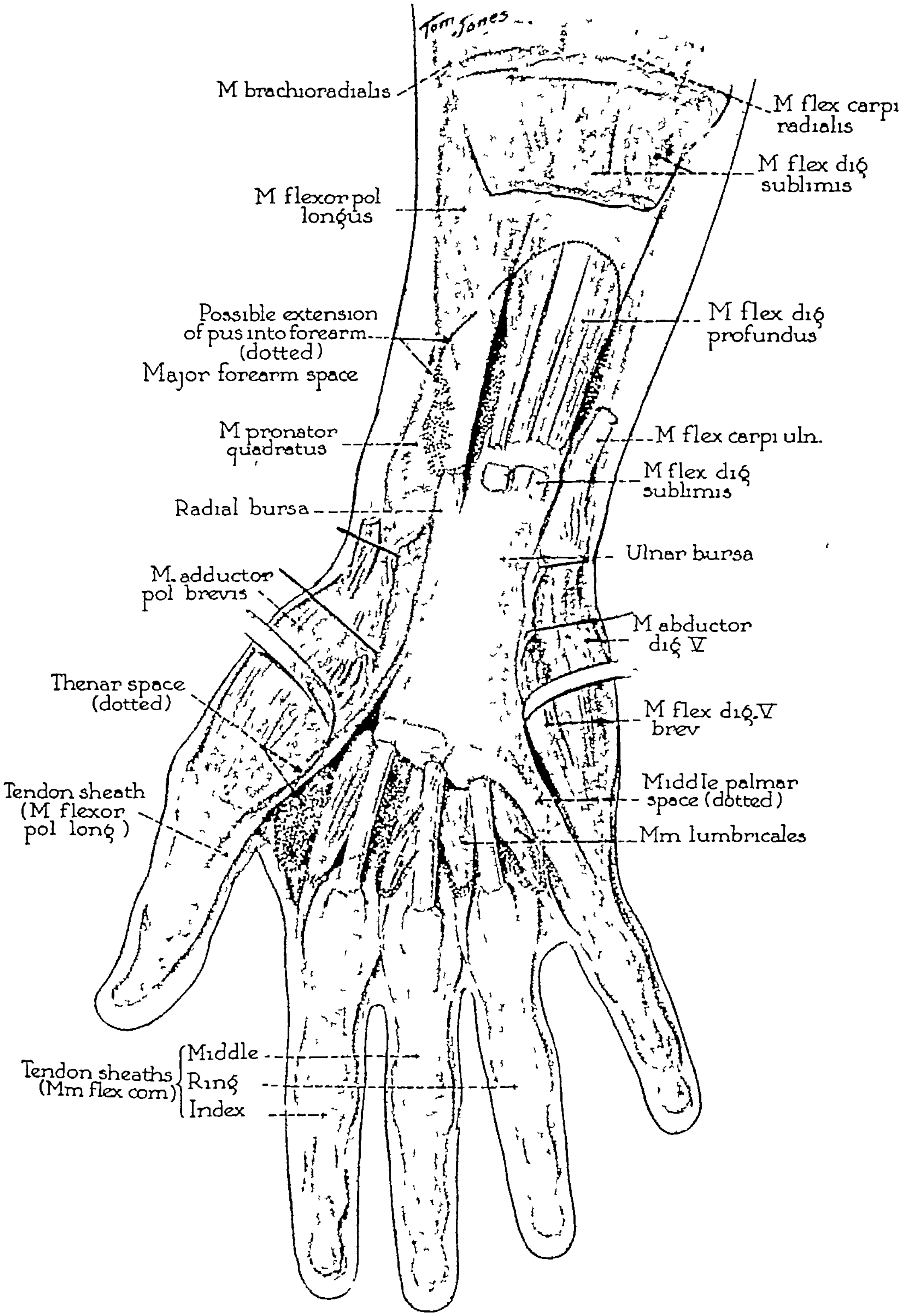


The relation of the synovial sheaths of the tendons and of the thenar space, middle palmar space and major forearm space to various structures of the hand and forearm Note that the spaces lie dorsal to the tendons and muscles

INFECTIONS OF THE HAND

A GUIDE TO
THE SURGICAL TREATMENT OF
ACUTE AND CHRONIC
SUPPURATIVE PROCESSES
IN THE FINGERS, HAND AND FOREARM

By ALLEN B. KANAVEL, M.D., Sc.D.

Professor of Surgery, Northwestern University Medical School, Chicago
Attending Surgeon, Wesley Memorial and Passavant Memorial Hospitals, Chicago

Sixth Edition, Thoroughly Revised

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PREFACE TO THE SIXTH EDITION.

THE present edition of the study of the anatomy, pathology, and treatment of infections of the hand presents much new material in addition to a radical revision of the old. The new subject matter consists of our later investigations of correlated problems such as: the peculiar course of infections from bites and injuries from the teeth (Koch, Mason), the pathology and treatment of metacarpo-phalangeal joint infections, of gangrenous infections, of injuries from indelible pencils, of cattle-hair and other peculiar infections. Chapters have been added upon the function of the hand, the use of splints, and the prophylactic treatment of injuries. In addition almost every chapter has been revised in the light of our experience during the last twenty years

There has also been a radical change in the order and manner of presentation of the entire subject. Owing to the fact that, at the time of the first publication, deductions were made as to the pathological anatomy of infections of the hand quite different from the prevalent conceptions, and recommendations as to treatment which were not then accepted by the profession, it was thought necessary to support the assertions made by anatomical and experimental proof placed in juxtaposition to the clinical considerations of the respective subjects. As a consequence, the various phases of the subject were presented as each of the problems had been worked out in the anatomical and experimental laboratories of the Northwestern University Medical School, Chicago, Ill. It was realized that this deductive form of presentation

entailed closer study by the student and impaired the clarity of presentation, but it was feared that the dogmatic statements of new conceptions not closely correlated with corroborative evidence might militate against their general acceptance. In the two decades that have passed, however, the principles presented in the original contribution have been verified by other investigators, and the efficacy of the methods of treatment corroborated by other surgeons by the conclusive test of practical application It is thought, therefore, that a change to a simpler form of presentation is justifiable and as a consequence, in the present edition, the subject matter is arranged in the more conventional style of a text-book, with the discussion of the anatomy and of the experimental investigations separated from the clinical studies. This makes possible the presentation of the diagnosis and treatment of the various clinical entities in proper sequence, with greater simplicity and in a form more quickly grasped by students and practitioners

Many illustrations have been added to clarify the anatomy of the hand and the surgical procedures described It must be confessed that it is with some personal regret that I have also replaced several of the old illustrations with others that were more satisfactory It has seemed like abandoning old friends, since many of the illustrations were drawn from rude sketches made by myself during the laboratory studies, but they lacked the clarity that Mr Tom Jones, with his appreciation of the value of accurate anatomy and his artistic skill, has been able to give those replacing them He has also, with the permission of the Eastman Teaching Films, Inc , redrawn several of my illustrations from the film "Diagnosis and Treatment of Infections of the Hand"

I am deeply grateful for the kindly reception that these studies have received and have appreciated the many helpful suggestions from the profession everywhere. Drs.

Harry E. Mock, Frederic A. Besley and Loyal A. Shoudy, because of their wide experience in traumatic surgery have been of great assistance in the preparation of the chapter dealing with the prophylactic treatment of wounds and the care of employees in industry. Prof. A. A. Day, of the Bacteriological, and Miss Gertrude Beard of the Physiotherapy Departments of the Medical School have aided with their critical knowledge in the revision of the chapters dealing with these subjects. My associates, Drs. Sumner Koch and Michel Mason, have for many years been associated with me in the study of the surgery of the hand, and I have throughout this revision availed myself of their criticism and help. A particular indebtedness is acknowledged to Miss Mertie Spencer and Miss Margaret Prime, who have aided me in the preparation of the manuscript, and to the publishers who have met every suggestion so generously

In conclusion, it should be emphasized that there are two lesions, lymphangitis and suppurative tenosynovitis, still too often unrecognized and improperly treated In lymphangitis hasty incisions not infrequently lead to unnecessary loss of life, and in suppurative tenosynovitis the pathological condition is not recognized, and the failure to institute early treatment leads to prolonged illness and permanent disability The student is urged particularly to familiarize himself with the diagnosis and treatment of these two grave types of infection

A B. K

CHICAGO, ILL

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INFECTIONS OF THE HAND.

CHAPTER I

INTRODUCTION

SCOPE AND CLASSIFICATION OF TYPES OF INFECTIONS.

THE accompanying contribution to our knowledge of infections of the hand is the result of many years' study, comprising experimental and anatomical investigations carried on in conjunction with careful clinical observation of a considerable number of patients In the following pages the diagnostic factors and methods of treatment which this work has suggested will be described Experience has shown that with careful diagnosis, properly placed incisions and efficient after-treatment, we may expect a restoration to complete function in 95 per cent of the abscesses of the fascial spaces; while in tendon-sheath infections the morbidity will be reduced by fully one-half, and a greater reduction is possible if the profession as a whole will learn to make an early diagnosis in this most lamentable complication.

HISTORY

Professor Albert[1] says that while the word panaritium was not used by Celsus, it is found in the Arabian and other ancient writings, and appears to be a corruption of the Greek παρουγιά (παρά ὄνυξ) Paracelsus, Dorneus, and others have used the words pandalitium, passa, panaris, and panarium, and it cannot be said whether these refer to different types or are corruptions of the same word

[1] Chir , 1885, vol 2

Polaillon and LeDentu supported the theories of Gosselin, although the latter was led to admit that the theories of Dolbeau might have some justification in a few cases. Since that time the subject has received little attention but we have gradually come to believe that each party was too radical in its claims and that infection can spread by either channel, an assumption that every clinician has had occasion to verify

In later years a carefully observed series of cases was reported from the Greifswald Clinic by Max Tornier,[1] who brought prominently before the profession Helferich's method of opening widely the sheaths, which was later substantiated and discussed with carefully observed cases by Forssell[2]

I wish to make acknowledgment of my indebtedness to these able contributors Forssell particularly has written a most masterly article upon tenosynovitis. I am forced, however, to take issue with him as to certain methods of treatment Concerning these and the various modern ideas as to the treatment of tenosynovitis, full reference will be found in the chapter dealing with that subject.

In spite of the fact that from earliest times the importance of the subject has been recognized, neither in text-books nor in special articles can the student find clear descriptions of the various types of acute infections, with the methods of their diagnosis and treatment. These I shall here attempt to present.

SCOPE AND CLASSIFICATION OF TYPES.

It is manifest that if we are to have a clear idea of the various phases of infections of the hand, it will be necessary to divide the subject into various types, depending

[1] Beiträge zur Kenntnis schwerer Phlegmonen Inaugural Dissertation, Greifswald, 1891

[2] Klinische Beiträge zur Kenntnis der akut septischen Eiterungen der Sehnenscheiden der Hohlhand besonders mit Rücksicht auf die Therapie Nordiskt medicinskt Arkiv, 1903, Abt 1, Heft 3

Concerning the elemental meaning of panaritium, Forestus[1] states: "*Panaritium s. Paronychia tumor edicitur, calidus, ulcerosus, summe dolorosus, accidens in summitate digitorum, in latere unguis et quandoque tam vehementer afficiens, ut vigilias et inquietudinem excitet.*"

Our anatomical knowledge of the lymphatic vessels dates back to the time of Aristotle, but it is to Herophilus (300 B.C.) and Herasistratus (280 B.C.), according to the Galenic writings, that we ought to attribute the discovery of the chyliferous vessels. These observations fell into obscurity, and it was not until 1532, when Nicolas Masse discovered renal lymphatics, that the knowledge of the subject began to grow. Following Eustachius, Asselli, and others, Vessling and Rudbeck in the seventeenth century described lymphatics in the liver, pancreas lungs, and pelvis. Mascagni, Lippi, and Lauth followed with admirable work, while Sappey, in 1876, published his large atlas after twenty years of work, when the subject can be said to have been put upon a scientific basis.

It was shortly before this time, however, that the study of lymphatic abscesses was begun. Bauchet's[2] treatise, in 1859, upon infections of the hand lacked this knowledge to make it a masterpiece. From this time until the culmination of Sappey's work an acrimonious discussion was maintained over the subject of lymphatic *versus* synovial sheath extension of infection. Gosselin, following dissections, adduced proof that extension nearly always progressed along synovial sheaths. Dolbeau meanwhile presented a masterly discussion, supported by clinical evidence, in support of the possibility of lymphatic extension with the formation of deep abscesses. Chevalet,[3] a pupil of Dolbeau, chose for his doctorate thesis, in 1875, to make a further contribution to the literature in support of his master's assumptions, bringing to his aid the brilliant investigations of Sappey and others. Later,

[1] Chir., lib. v, Observat. 16.

[2] Du Panaris, Paris, 1859.

[3] Thèse pour le doctorate en médecine, Paris, 1875.

synovitis or fascial-space infection, in a great majority of cases it remains a clinical and pathological entity, and the mistake frequently made of assuming its association with either a tendon-sheath or fascial-space infection and treating it accordingly is responsible for the gravest errors and most serious consequences, both as to morbidity and mortality.

In a great majority of cases the differentiation of these types can be made, but I know of no single rule by which it can be done The requisite knowledge comes only with a clear understanding of the basic principles of inflammation produced by the various bacteria, coupled with a knowledge of the anatomical relations peculiar to the hand and a study of the course any given infection will normally pursue It has therefore seemed necessary to give in some detail the anatomical and experimental investigations upon which my deductions are based, rather than to state dogmatically the rules upon which a diagnosis should be made and the various incisions which I have found to lead to the most rapid recovery If one will take the time to fix in mind the fundamental facts which are here discussed, he will have no difficulty in applying them to any given case The technical procedures incident to the operations are easily learned and applied In almost all cases the difficulty has been an improper diagnosis, both as to the nature of the infection and the position of the pus It is urged that the surgeon take the time to acquaint himself with the anatomy in relation to infections as presented in the accompanying chapters

Also, I wish to emphasize that while for the sake of clearness a brief résumé of the contents has been introduced into certain chapters, the careful surgeon will find it necessary to read the context for the coordination of the various data

It will be found that lymphatic infections follow a distinct anatomical and clinical course, having at all

upon the nature of the infection and the results it produces It should be understood that we are dealing with acute infective processes, and not those associated with syphilis, tuberculosis, and other chronic infections, although the general principles laid down by the anatomical and experimental researches will be found to be applicable there also

I have divided the subject in general as follows.

Part I Anatomy and General Principles.

Part II. Clinical Entities Exclusive of Lymphangitis, Major Fascial-space and Tendon-sheath Infections

Part III Lymphangitis, Major Fascial-space and Tendon-sheath Infections

Part IV Complications, Sequelæ, and After-treatment of Infections of the Hand.

It is true that these various types of infection may overlap, nevertheless each is a clinical entity If each type is understood with a knowledge of the methods of its diagnosis and treatment, the proper care of the complicated case is made easy. This is particularly true in relation to lymphangitis, major fascial-space and tendon-sheath infections where all three types may be present, although in a majority of cases only one will be found if treatment has been instituted in the early stages of the infection

If they are combined, the symptoms and signs of each are present, and each will demand a separate and distinct form of treatment, for in opening a synovial-sheath infection we do not by any means drain the fascial spaces, nor *vice versa* Again, unless we have a clear picture in our minds of the two types we might, in draining one when the other is not involved, by an ill-advised incision produce an extension into the uninvolved tendon sheath or fascial space, and in a patient who depends upon his hands for his livelihood, such an error becomes criminal carelessness

Again, while a lymphangitis may become a teno-

PART I.

The Anatomy and General Principles Peculiar to Infections of the Hand.

CHAPTER II

METHODS OF STUDY IN GENERAL· STUDY OF SERIAL CROSS-SECTIONS OF THE HAND, WITH PARTICULAR RELATION TO THE FASCIAL SPACES.

UPON beginning the study of infections of the hand it was realized immediately that our general knowledge of the anatomy was entirely inadequate when we came to apply it to specific conditions The first problem, therefore, with which we had to deal was a thorough study of the anatomy carried out entirely in relation to infections. As the work progressed, the reasons for many failures in the care of these cases were seen We are firmly convinced that anyone who wishes to master the proper steps in the diagnosis and treatment of infections of the hand must follow step by step the unfolding of the anatomical picture as we shall try to present it in the subsequent pages

The anatomy peculiar to infections of the distal phalanx, the finger and that relating to knuckle injuries, frog felons and carbuncles will be presented in connection with the clinical considerations of these subjects

times the possibility of producing certain definite complications which may be prognosticated and anticipated

We shall see that the tendon-sheath infections pursue definite lines of invasion, and the position of the pocket of pus when rupture occurs can be prognosticated, so that incisions can be made early at these sites and further extensions prevented

Concerning the fascial spaces it will be shown that:

(*a*) There are certain well-defined, uniform spaces upon the fingers, palm, dorsum of the hand, and forearm in which pus can accumulate

(*b*) There are definite anatomical channels by which infection originating in a given site will extend to certain of these spaces, while certain other spaces will remain uninvolved, hence the diagnosis of the position of the pus is simplified and the proper site for the incision determined

(*c*) There are definite anatomical channels by which pus can spread from the uniform spaces mentioned, and when this occurs, the secondary locations of the pus can be prognosticated.

(*d*) The incisions for evacuation of pus in the various spaces must be made at definite sites, otherwise important structures may be injured, or by ill-advised incisions adjacent spaces or tendon sheaths may be opened at the same time and a spread of the infection favored to parts of the hand that would not have become involved without this unfortunate surgical procedure

(*e*) The infection may persist for weeks and months after apparently opening the pus pocket, if diverticula and intermediary chambers are not taken into consideration

The interrelation of these various facts will be emphasized by abbreviated case reports, each of which has been introduced to illustrate or clarify some important clinical fact The number could have been multiplied many times, but I have tried not to duplicate these illustrations

were made of a third hand at right angles to the metacarpal bone of the thumb, since it was found that the findings in the thenar area were somewhat confusing. This hand also was frozen, and, like the first and second, without much fat By these sections a fairly definite idea of the spaces was secured

2 To corroborate the findings above, as well as to determine their exact limitations, injections of pastes

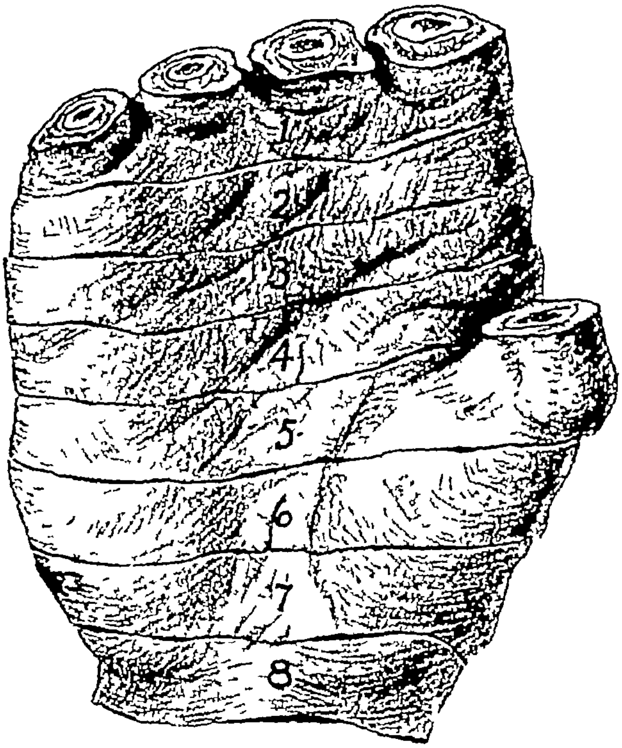


FIG 1 —Drawing made from specimen, showing sites of the various sections taken through the hand

were made into the various fascial spaces, by various channels, and with varying degrees of force This determined not alone the positions and relations of the pockets, but also by what channel pus could reach them and where it would extend if it broke through the walls of the closed fascial spaces By this method we also determined the course pus would pursue when it ruptured from the tendon sheaths, and thus fixed the relation of the tendon-sheath infections to fascial-space infections The

Anatomy of the Hand and Forearm in Relation to Infections

A. Anatomy of the hand
- I Methods of study
- II. Study of serial cross-sections with particular relation to fascial spaces
- III Study of the tendon sheaths in general
- IV Study of the major fascial spaces and tendon sheaths by means of experimental injections
- V Study of roentgen-ray pictures of injected hands
- VI Study of the embryology

B Anatomy of forearm
- I Anatomy in general
- II Study of serial cross-sections
- III Study by means of injection of the connective-tissue spaces

METHODS OF STUDY

1 With the object of securing a tentative picture of the fascial spaces and their relation to the tendon sheaths in particular and other structures in general, a freshly amputated cadaver hand was hardened in formalin and cross-sections made (about 1 cm in width), beginning at the end of the fingers and going as high as the elbow. The fascial layers were then teased out and their relations to the muscles, bones, tendons, nerves, and bloodvessels determined The prolongations of the various fascial spaces and tendon sheaths were followed from one section to another, thus, their limitations were determined and the relation of the various adjacent structures noted The specimen chosen was one with but little fat (Fig 1)

The same process was carried out in a fresh cadaver hand in which the vessels were injected with red lead and the sections cut while the hand was frozen Sections

anatomical peculiarities of the spaces and the embryological development

5 The clinical cases which came under observation were observed very carefully to see if the real pathology corresponded with the anatomical demonstration Bacteriological studies of all cases were made that we might investigate the relation between the variety of germs present and the tendency to spread It is a satisfaction to record that the deductions made by this early investigation have been verified by the clinical observations of myself, my associates and other clinicians during the twenty-five years that have elapsed since this study began.

A STUDY OF SERIAL CROSS-SECTIONS, WITH PARTICULAR RELATION TO THE FASCIAL SPACES

That we may follow the study of the serial cross-sections with more understanding, the following facts should be noted: Our study shows that upon the palmar surface we have three major fascial spaces, not communicating in any way with each other, and to these are given the names thenar, hypothenar, and middle palmar spaces respectively Certain channels will be found which lead directly into them Certain structures along which pus can pass will be noted lying in juxtaposition Again, minor anatomical chambers will be noted, especially in the thenar area and superficial to the tendons in the palm, these, however, need little or no consideration from a surgical standpoint, since they are unimportant, not likely to become infected separately, and if they do, they will rupture into one of the larger pockets

Upon the dorsum two areas will be found in each of which pus can accumulate to the exclusion of the other To these are given the names dorsal subcutaneous space and dorsal subaponeurotic space We shall find that

findings were very uniform and satisfactory, with the exception of three or four which did not reach the spaces intended The material used was such as is ordinarily found in the dissecting room, hence, while the part was always well preserved, in some cases the material was more friable than in others, and, therefore, rupture from the space was more likely to occur. However, this does not interfere with the deductions, since the changes present were, in a measure, comparable to those found in inflammatory processes Moreover, no matter whether the tissue was fresh or preserved, the findings were the same, so we may feel sure that the results are to be depended upon

The fascial spaces of 56 hands and forearms were injected from various sites with plaster of Paris, which had been rubbed up with glycerin and diluted with water. It was injected by means of a hand pump through a cannula, which was inserted at various points, as will be noted later As the hands were dissected, the location and paths of extension of the masses were noted In those cases injected with moderate force a pressure of 4 to 8 pounds was used, and where forcible injection is noted, 25 to 35 pounds

3 Several hands were injected as above, except that the injected mass was impregnated with red lead Roentgen-ray pictures were taken This showed the relation of the theoretical pus accumulations to the bones and bloodvessels, the latter having been injected with the same mass Again in other hands, injections of various spaces were made, concomitant with injections of the synovial sheaths, to show their relation and the proper site for operations designed to open the former without injury to the latter

4 After this work had been done a study of the embryology was made, with a view of determining whether or not there was any relation between the

sheaths, which sheaths are so closely united to the periosteum that no definite free spaces can be found.

The importance of the close attachment of the tendon sheath to the bone will be brought out when discussing tendon-sheath infection in relation to the frequency of osteomyelitis secondary to this trouble

The spaces above mentioned all pass through this serial section into the next, the second cross-cut being made through the epiphysis of the proximal phalanx.

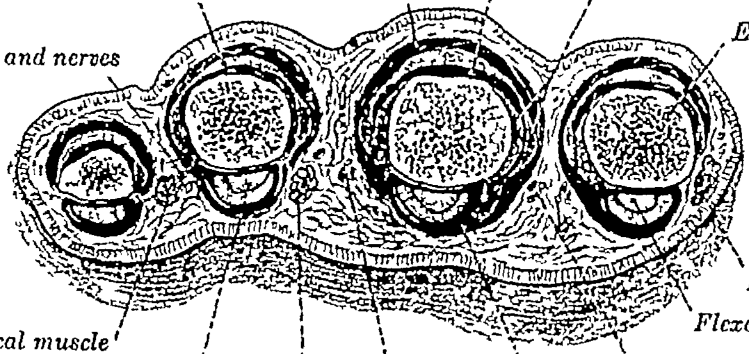


FIG 3 —Cross-section No II Through epiphysis of proximal phalanx The tendon sheaths are shown in red

Section II. (Fig 3) In this section the salient points may be pointed out briefly, so that we can retain a composite picture with that which has just been described.

The dorsal subcutaneous space is continuous with that in Section I

The dorsal subaponeurotic space is also continuous and the interosseus muscles begin to appear—one part attached to the periosteum and one part to the dorsal aponeurotic sheet. More important still, we see the beginning of the lumbrical muscles, and note particularly the relation of this muscle to the subcutaneous space, especially in the third finger.

while the pus may lie at various anatomical levels in the subcutaneous tissue, yet for surgical purposes any subdivision of this space is unnecessary and confusing.

Section I Beginning with a cross-section which lies just distal to the web of the fingers, we note the following facts The index finger is slightly different from the middle and ring fingers in that the space which is most superficial, and which we will call "the subcutaneous space," does not extend around the entire finger, as do the others, but at the radial side the perifascial space tissue is so dense as to obliterate it. It will be noted that this space lies deep under considerable tissue which

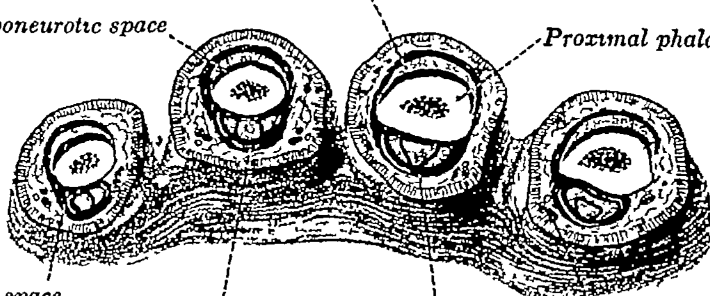


FIG 2 —Cross-section No I The tendon sheaths are shown in red

is rather dense If this tissue is infected the pus will come to the surface or infect the subjacent space above mentioned, where it will have little difficulty in spreading proximally or distally (Fig 2)

The little finger corresponds with the index finger in that the space is partially obliterated upon its ulnar side. Between the extensor tendon and the bone in each of the four fingers there is a second connective-tissue space, and to this we will give the name of "dorsal subaponeurotic space of the finger," for upon each side of the tendon a dense sheet of tissue is given off, which unites firmly with the periosteum at each side. Upon the flexor surface are found the flexor tendons in their synovial

section is seen upon a cut 0.5 cm proximal to the metacarpo-phalangeal joint (Fig 4).

In this section the subaponeurotic space, except for small diverticula lying between the two parts of the interosseus muscle, has disappeared.

The subcutaneous space between the fingers is also obliterated. It is continued, however, in the dorsal subcutaneous space which joins the space about the lumbrical muscle.

The spaces about the lumbrical muscles are well marked and should be followed carefully into the palm.

There is here a dense layer of tissue that crosses the whole section lying around and over the tendon sheaths and under the lumbrical muscles.

The flexor tendons are surrounded by their sheaths

The spaces are all obliterated in passing through either this section or the previous one, except the synovial space about the flexor tendons, those about the lumbrical muscles, and the slight channels, above noted, connecting the dorsal subcutaneous tissue of the fingers and the spaces about the lumbrical muscles

The surgical application of this will be brought out later

Section IV The fourth cross-section lies 2 cm above the metacarpo-phalangeal joint (Fig 5)

The dorsal subaponeurotic spaces, which were obliterated at the joint, are beginning again between each tendon and the corresponding bone

The dorsal subcutaneous spaces approximate each other

The palmar tissue is still dense, with no free passages except those about the lumbrical muscles and those along the sheaths of the tendons which are still present, but begin to be obliterated as they pass through this serial section

As yet no space has appeared into which pus would extend if it were to pass proximally along these synovial

The flexor tendons are still covered by their synovial sheaths

Ask youself where pus would go to if it followed down along the lumbrical muscle from the palm As we follow these spaces into the next section, we will see that the subcutaneous spaces upon the abutting sides of the fingers merge into each other, that is to say, for example, the subcutaneous spaces of the ulnar side of the index finger and the radial side of the middle finger join at the web, being in close relation to the lumbrical muscles.

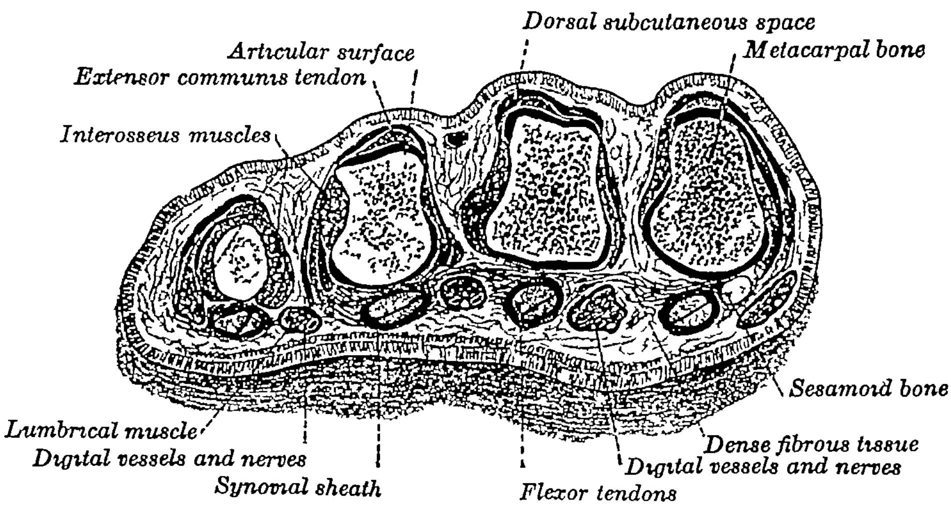


FIG 4 —Cross-section No III Proximal to metacarpo-phalangeal joint The tendon sheaths are shown in red

Slightly proximal to this, as will be seen in the next serial section, the space is obliterated between the fingers, and only a small part remains upon the dorsum of each finger It should be noted, however, that this small part is continuous with the space about the lumbrical muscle in the palm, so that pus may spread from the palm downward into this space and thus point on the dorsum (For schematic drawing showing this, see Fig 188) The dorsal subaponeurotic space is obliterated in this section, *i e*, at the joint

Section III The distal surface of the third serial

Now let us imagine ourselves following through this serial section into the next The free, open spaces of the hand appear suddenly, the synovial sheaths of the tendons become obliterated after entering them, the lumbrical muscles join the tendons and the spaces around these muscles have merged into the middle palmar and thenar spaces The adductor pollicis (transversus) which is the keynote to the thenar space begins to assume its characteristic relations

Section V In a cross-section about 3 cm. proximal to the metacarpo-phalangeal joint, we find the following, which is well represented in Fig. 6.

The Middle Palmar Space

There is a large, free space with few fibrous septa extending from the middle metacarpal bone to the radial side of the metacarpal bone of the little finger. It is bounded dorsally by a thin fibrous sheet which overlies the anterior interosseous membrane and the interosseus muscles, upon its palmar side is a second thin sheet separating it from the tendons and the lumbrical muscles of the little, ring and middle fingers and the loft above them The space is limited upon its ulnar side by dense, fibrous tissue, and upon its radial side by a dense, fibrous sheet which is attached to the middle metacarpal bone This space is probably the most important in the hand, and to it is given the name of "Middle Palmar Space"

If we were to note the layers of tissue through the middle of the hand, going from the palm to the dorsum, they would be as follows

1 Epidermis
2. Dermis
3 Firmly meshed subdermal connective tissue
4 Palmar aponeurosis
5 Loose mesh of connective tissue, in which lie (*a*)

sheaths We note, however, that a small space has appeared just volar to the small piece of adductor pollicis (transversus) muscle, which will become the thenar space

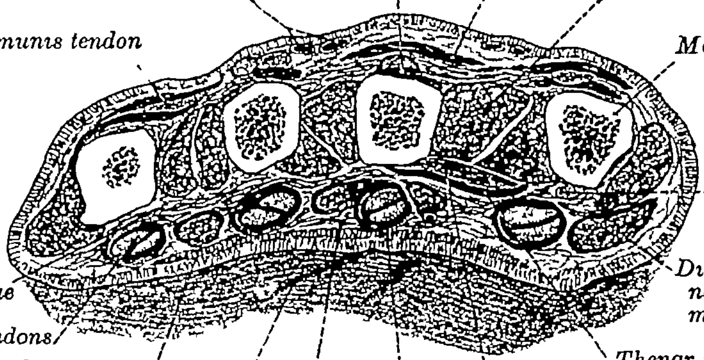


FIG 5 —Cross-section No IV Two cm proximal to joint The tendon sheaths are shown in red Note the beginning of the middle palmar space

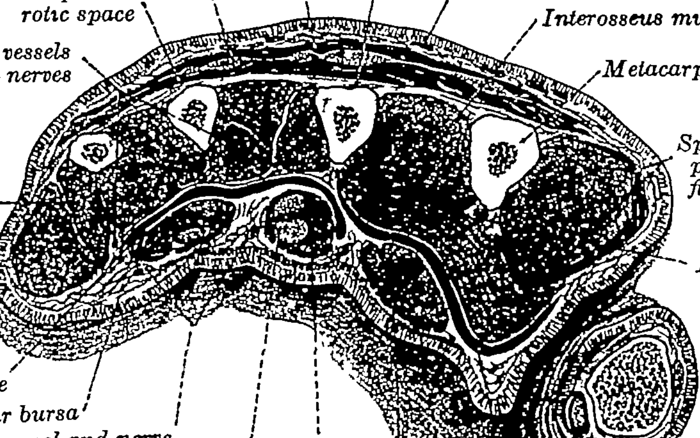


FIG 6 —Cross-section No V Three and a half cm proximal to joint The tendon sheaths are shown in red (ulnar bursa and radial bursa)

most important spaces in the hand, and it is well to note their relations to each other and to adjacent structures. They will be taken up later, and a composite picture made from the fragmentary description noted here and in the following serial sections.

Upon the dorsum the dorsal subcutaneous and subaponeurotic spaces are well shown.

The synovial sheaths have entirely disappeared except for a small prolongation along the little finger tendons—

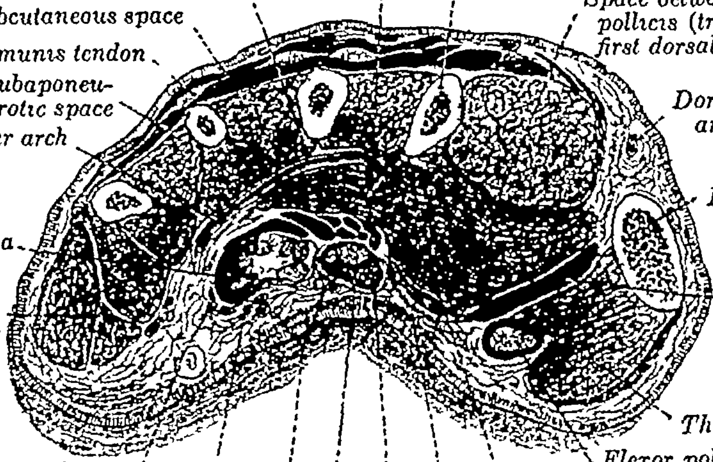


FIG 7 —Cross-section No VI Through distal part of thenar area The ulnar and radial bursæ are shown in red

the beginning of the ulnar bursa—and that about the flexor pollicis longus The tendon sheaths about the tendons of the other three fingers were obliterated while passing through this section The ulnar bursa, however, is seen to lie in juxtaposition to the middle palmar space as do the tendon sheaths of the middle and ring fingers distal to this section The tendon sheath of the index finger is in close connection with the thenar space

Section VI (Fig 7). This serial section is taken through the distal part of the thenar eminence and thus

vessels and nerves, (*b*) tendons with lumbrical muscles, or endings of the synovial sheaths

6 Anterior middle palmar sheet

7 *Middle Palmar Space.*

8. Posterior middle palmar sheet

9 Vessels

10 Palmar interosseous membrane, extending from bone to bone

11 Interosseus muscles

12 Posterior interosseous membrane

13 Dorsal subaponeurotic space filled with thin-meshed connective tissue and vessels

14 Dorsal aponeurosis and tendons

15 Dorsal subcutaneous space, with loose connective tissue

16 Dermis

17. Epidermis

THE THENAR SPACE

Upon the radial side we note the large mass of the adductor pollicis (transversus), and upon its palmar side is shown a large space extending from the metacarpal bone of the middle finger over the muscle to the radial side of the hand, turning dorsalwards here under the skin to reach the level of the flexor surface of the metacarpal bone of the index finger, or, in other words, being L-shaped in cross-section It will be seen later that this limitation is of importance, since it prevents injection masses from passing freely to the dorsum of the hand, or *vice versa* This space is known as the "Thenar Space" Upon its palmar side there is a dense layer of tissue, blending with the palmar fascia, and between this dense palmar tissue and the space lie the tendon and lumbrical muscle of the index finger The adductor muscle is covered by a thin layer of tissue or perimuscular sheath

The middle palmar and thenar spaces are the two

They are still separated by a thin fascial sheet, however, in those specimens examined.

One or two indefinite spaces are present about the thenar region. They are of little importance, however, except to note that they are present between the groups of muscles, and localized infection can occur in them under exceptional circumstances.

The dorsal spaces remain the same, except that the subaponeurotic is more constricted

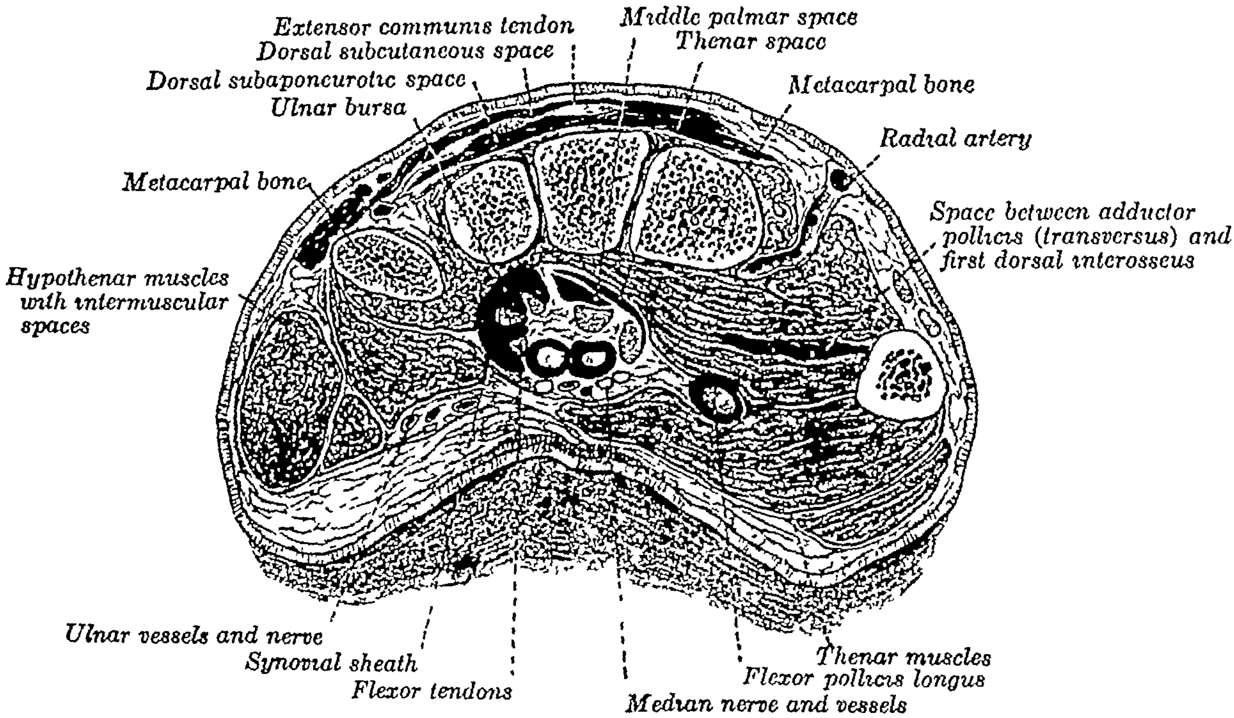


FIG 8 —Cross-section No VII The ulnar and radial bursæ and the intermediate tendon sheaths are outlined in red

The tendon sheaths are seen in four places—the ulnar bursa, the sheath about the flexor pollicis longus, and the two intermediate sheaths about the superficial tendons in juxtaposition to the ulnar bursa

THE HYPOTHENAR SPACE.

Nothing as yet has been said of the hypothenar area, since it was desirable to avoid confusion However, a glance at this section, and at those which have preceded

shows the metacarpal bone of the thumb in cross-section. Here we note the great relative size of the thenar space, and yet it is all upon the radial side of the middle metacarpal. The lumbrical muscle and index tendons are separated from it by a much thinner septum than in the previous section. The tendon of the flexor pollicis longus appears here surrounded by its synovial sheath.

The middle palmar space is much smaller and still lies under the group of tendons of the middle, ring, and little fingers. Upon the ulnar side of this group we see the ulnar synovial bursa in juxtaposition to the space, yet the septum between them must be relatively strong since the injection masses in this bursa, noted later, have a greater tendency to rupture into the forearm than into this space.

Upon the dorsum we still find our subaponeurotic and subcutaneous spaces, while over the thenar area the subcutaneous tissue is also lax, and either of the two former spaces can be made to communicate with it.

The deep palmar arch appears in this section, and its relation to the middle palmar space and the synovial sheath should be noted. We see that there is not much danger of injuring it if care is taken in operating.

In the cases examined the flexor pollicis longus with its tendon sheath is separated from the thenar space by a considerable amount of tissue, and while rupture from it into the space is possible (particularly in those cases accompanied by inflammatory destruction), yet it would be more likely to rupture at the upper end of the synovial sac into the cellular tissue of the forearm. Experimental evidence to support this will be brought forward later.

Section VII (Fig. 8.) In the seventh section, taken through the base of the palm, the middle palmar space and the thenar space are seen to have shrunk into insignificance. They lie close together under the group of tendons, the middle palmar space being more superficial.

The dorsal subcutaneous space can be demonstrated, but it is more difficult to do so here than in the previous sections, since more of the fibers tend to intermingle from layer to layer

The synovial sheaths about the dorsal tendons also appear in this section

Discussion of the Relations of the Middle Palmar and Thenar Spaces

The inter-relation of the middle palmar and thenar spaces is of very great interest to the surgeon, and to understand it the roof and floor of the two spaces must be discussed together They are separated from each other at the middle metacarpal bone by firm septa so that neither one communicates with the other, nor does either overlap to the other side of this bone. The tendons of the third and fourth fingers, with their lumbrical muscles, lie just above the middle palmar space, separated from it by only a thin, indefinite membrane, while upon the palmar side of this group is some loose connective tissue with indefinite spaces, but pus, if it located here, must pass around the tendons to their dorsal surface and rupture into the middle palmar space, since in every other direction firm tissue is found Such a course would be followed in an infection passing upward along the lumbrical muscles If it follows along the synovial sheath of the ring finger, and finally ruptures from the proximal blind end, it will pass ultimately into this space The same holds true for the tendon sheath of the little finger in those cases in which it is separated from the ulnar bursa To the ulnar side of the tendon of the little finger is seen the small synovial space representing the continuation of the synovial sheath of the little finger into the synovial sheath of the tendons above, known as the ulnar bursa

shows very clearly that while it is possible for pus to accumulate in the intermuscular spaces, yet it would be absolutely localized here, and would spread to the surface It would not enter either the middle palmar space or the ulnar synovial bursa Such infections would be of little surgical interest, owing to their localized nature

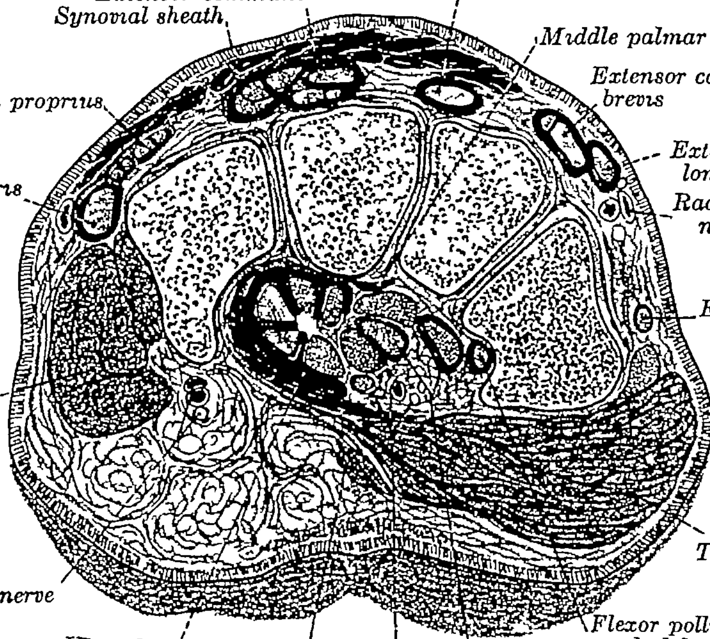


FIG 9 —Cross-section No VIII The ulnar bursa, radial bursa, and intermediate and dorsal sheaths are shown in red

Section VIII (Fig 9) In the eighth section, taken at the wrist, the middle palmar and thenar spaces can still be found, but they are so small as to be of little practical importance, since any inflammation in them would probably be followed by closure Their behavior under forcible injection will be noted later

While it might be possible by forcible injection to produce a dorsal subaponeurotic space, yet it should not be described as being present.

muscles would still offer a slight resistance, for there is no distinct channel leading to the dorsum, although the intermuscular septa do tend in that direction Having come through these, however, the pus would then meet the septum passing from one bone to the other upon the dorsal surface of the interosseus muscles If the pus meets and overcomes the various obstructions, which it might do in chronic and exceptional cases, it would then lie beneath the tendons upon the dorsal surface, or in the dorsal subaponeurotic space It is evident, therefore, that infections uncomplicated by osteomyelitis would seldom pass directly through to the dorsum Experimental and clinical evidence shows that extension to the dorsum occurs through passage of the pus distally along the lumbrical muscles, thence to the dorsum at the web

Now let us go back to the thenar space and its floor, or dorsal wall This is slightly more complex, in that the muscular masses making up the floor confuse us For the most part it is made up of the adductor pollicis (transversus) and the adductor pollicis (obliquus), and in those cases where there is little tension upon the contents it would be limited dorsally by them and the thin sheet of fascia over the muscles Upon the other hand, if the tension were increased, it would be very easy for the contents of the cavity to pass between these muscles and come to lie upon the dorsal surface of the adductor pollicis (transversus) That is to say, it would come against the first dorsal interosseus upon the dorsum of the thenar region about on a level with the metacarpophalangeal joint of the thumb, and thus, if there were any inflammatory action present, spread to the cutaneous tissue at the web, or, if the dorsal interosseus muscles were unimportant, in the dorsal subcutaneous tissue of the thenar region Experimental evidence will be adduced later to prove this can occur

It will be seen that the lumbrical muscle and tendons of the index finger occupy the same relative position to the thenar space that the third and fourth do to the middle palmar space, with this exception, that in those hands which have been examined the sheet of tissue separating it from the thenar space is somewhat firmer, still, it is not so dense as that upon the other three sides, hence if pus ruptures from the synovial sheath of the index finger or passes proximally along the muscle it will rupture into the thenar space

The lumbrical muscle and tendon of the middle finger in Section VI occupy an intermediary place between the two spaces, but in the previous section they will be seen to lie over the middle palmar space at which site the enveloping fascia is much thinner, so that we would have reasons to believe, from an anatomical standpoint, that pus spreading along this tendon would communicate more easily with the middle palmar space, and experimental injections of the synovial sheath substantiate this reasoning

We have now discussed all of the relations of these spaces except the floor, or dorsal surface, and the proximal prolongation The latter we will speak of in the chapter dealing with Anatomy of the Forearm Concerning the floor, however, it is well to mention several things Owing to the closed nature of these pockets, it is customary for clinicians to draw attention to the probability of rupture from them, through between the bones, to the dorsal surface

In the middle palmar space the floor is composed of a very thin fascial layer, through which pus could rupture easily, were it not for the support given it by the interosseus muscles and the interosseous membrane, upon which it lies Should inflammatory destruction of this sheet arise, however, or rupture ensue, the interosseus

the proximal end of the space under the tendons and ulnar bursa at the wrist into the forearm

6 The web space, an area of loose connective tissue between the bases of the fingers extending distally into the subcutaneous tissue at the sides of the fingers, and dorsally into the subcutaneous tissue of the dorsum and proximally into the connective-tissue spaces around the lumbrical muscle on the palmar surface

The corroboration of our statements as to the outlines of these spaces will be brought out in the chapter upon experimental injections (Chapter IV)

7 The major fascial space in the forearm will be considered in the chapters dealing with the "Anatomy of the Forearm"

In the chapter dealing with the "Function of the Hand" the results of our studies upon the embryology of the hand have been presented in abstract form. They explain and emphasize the division of the palm into middle palmar and thenar spaces

Résumé

We note that in the hand we have six major fascial spaces with their tributaries in which pus can accumulate In describing the anatomy of the forearm a seventh will be described These I have designated as major fascial spaces

1 The dorsal subcutaneous, which is an extensive area of loose tissue, without definite boundaries, allowing pus to spread over the entire dorsum of the hand

2 The dorsal subaponeurotic, limited upon its subcutaneous side by the dense tendinous aponeurosis of the extensor tendons, upon the deep side by the metacarpal bones, having the shape of a truncated cone, with the smaller end at the wrist and the broader at the knuckles Laterally the aponeurotic sheet shades off into the subcutaneous tissue

3 The hypothenar area, a distinctly localized space, not communicating with the other spaces, and not having a relation to any tendon sheath

4 The thenar space, occupying, approximately, the area between the thenar eminence and the middle metacarpal bone Superficially its ulnar boundary is indicated by the adduction crease of the thumb It lies entirely upon the radial side of the middle metacarpal It should be remembered that this space lies deep in the palm, just superficial to the adductor pollicis (transversus)

5 The middle palmar space, with its three diverticula distal along the lumbrical muscles, limited by the middle metacarpal bone upon the radial side, overlapped by the ulnar bursa upon the ulnar side, and separated from the thenar space by a partition which is very firm everywhere except at the proximal end, where it is rather thin Superficial to it and the anterior palmar sheet is an area of loose connective tissue containing tendons, nerves and bloodvessels A small isthmus can be found leading from

THE SHEATHS OF THE INDEX, MIDDLE AND RING FINGERS.

These begin just distal to the distal interphalangeal joint and extend into the palm, approximately a thumb's breadth proximal to the web, or the point of extension can be designated by drawing a line between the end of the proximal palmar crease at the base of the index finger and the end of the distal palmar crease at the base of the little finger This line represents the approximate extension of these sheaths into the palm It will be seen by noting Fig 5 that at the distal portion of the palm there is a sheet of dense tissue enclosing the tendon sheaths and lumbrical muscles The sheaths extend ¼ inch proximal to this into the loose palmar tissue adjacent to the major palmar spaces This fact is of considerable importance from a surgical standpoint (see pp 60 and 327)

While passing through the dense tissue mentioned above, these sheaths have on either side the space called the lumbrical canal, through which pass the lumbrical muscles and digital branches of the arteries and nerves (Fig 4) This is also of surgical importance (see pp 338 and 372)

As we pass distally, we find considerable tissue between the metacarpo-phalangeal joint and the sheath proper, while more distally, as we come to the base of the proximal phalanx, we note that the sheath approaches the bone and is in close relation with the loose connective tissue going entirely around the bone The surgical importance of this will be brought out later

At the proximal interphalangeal joint (Fig 181) we find considerable tissue between the sheath and the joint, while over the base of the middle phalanx, *i e*, at the epiphyseal line (Fig 10), there is little or no tissue between the sheath and the bone From this point distally the relation to the bone is not so intimate At

CHAPTER III.

THE TENDON SHEATHS· A DISCUSSION OF THEIR ANATOMICAL DISTRIBUTION AND RELATIONS, WITH SURGICAL DEDUCTIONS

FROM a consideration of the cross-sections we have described in the previous chapters it is possible to give a composite picture of the various tendon sheaths from an anatomical and surgical standpoint In the following description the well-known anatomical points which have no bearing on the subject in hand will not be dealt with It is my intention to emphasize those facts which will aid us in understanding the course an infection will pursue, and will point to the proper course of treatment Therefore, before reading this the student should have a clear conception of the anatomy of the six fascial spaces described in the previous chapter

The particular relation of the sheaths to the six fascial spaces will be emphasized in the chapter dealing with experimental injections (Chapter IV) These injection results will also serve to corroborate the anatomical statements made here

SHEATHS UPON THE FLEXOR SURFACE

From a surgical standpoint, the sheaths upon the flexor surface are the most important The anatomy of these may be discussed under four heads (1) The tendon sheaths for the index, middle, and ring fingers, (2) the tendon sheath for the thumb with its prolongation in the hand (radial bursa), (3) the tendon sheath of the little finger and its prolongation in the palm (ulnar bursa), (4) the communications between these various sheaths

nearly always communicates with the enlarged sac of the tendon sheath at the wrist (19 in 20 cases, Poirier). The entire sheath has been given the name of radial bursa, although technically speaking it should be applied only to the proximal part at the wrist.

The sheath begins distally at the base of the distal phalanx and extends proximally a thumb's breadth proximal to the transverse carpal ligament. It lies first in close proximity to the proximal phalanx, but at the distal end of the metacarpal bone becomes separated from the bone by the muscles of the thumb lying between the outer head of the flexor pollicis brevis and the adductor pollicis (obliquus) (Figs. 7 and 8). At times (1 to 20, Poirier) there is a separation of the sheath into two parts about the middle of the metacarpal bone. This is frequently only a thin diaphragm The sheath is generally well separated by connective tissue from the metacarpo-phalangeal joint and an infection may spread from the joint to the sheath, or *vice versa*, but either extension is uncommon It lies superficial to the proximal end of the thenar space, in juxtaposition to the flexor tendons in the carpal canal (Fig 9) and passes upward to terminate about an inch above the annular ligament by a rounded cul-de-sac extending proximally under the deep surface of the tendon, and lying on the pronator quadratus

The communication between this and the ulnar bursa will be discussed later The motor nerve to the thenar muscles lies within a finger's breadth distal to the transverse carpal ligament and superficial to the sheath (see p. 416). Proximal to the transverse carpal ligament the tendons of the palmaris longus and the flexor carpi radialis lie above the radial bursa, and by drawing the tendon of the flexor carpi radialis to the radial side one can come down directly upon the flexor pollicis longus and its sheath Attention should likewise be drawn to the fact that the median nerve lies rather deeply between the two bursæ

the distal end the relation of the structures can be seen by studying Fig. 55 (For surgical application see Chapters IV and XXVII)

These sheaths bear almost the same relation to the respective fingers They differ, however, in their relation to the major palmar spaces The proximal end of the sheath for the index finger is in relation to the thenar space, while that of the middle finger is most often in relation to the middle palmar space, although at times it will allow of rupture into the thenar space, possibly through rupture into the lumbrical space between the

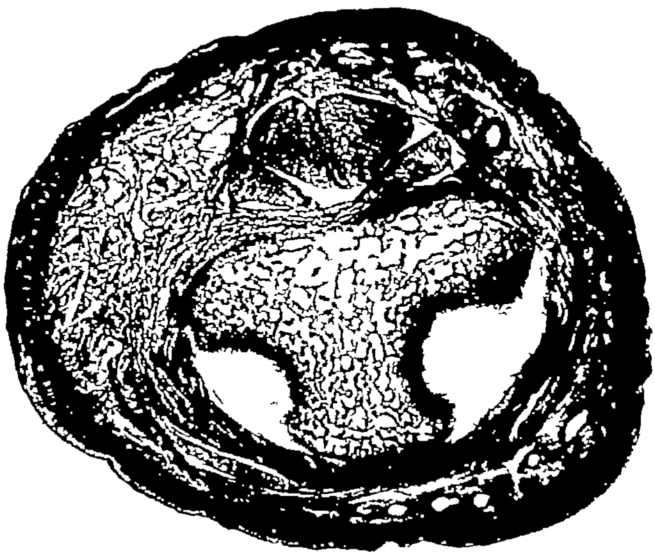


FIG 10 —Cross-section through the epiphysis of the middle phalanx Notice the loose mesh and the small amount of connective tissue between the tendon and the bone

index and middle finger and thence into the thenar space However, this lumbrical space itself most often leads into the middle palmar space The tendon sheaths of the ring finger and of the little finger are in relation to the middle palmar space

The Radial Bursa and the Tendon Sheath of the Flexor Pollicis Longus

This is of great importance from a surgical standpoint, owing to the fact that in youth and adult life the sheath

present it is of any grade, from a single narrowing to a complete occlusion some millimeters in length. In these cases the sheath corresponds in length to those of the other fingers Also the relations to the joints and spaces are the same except that there is no lumbrical canal upon the ulnar side of the proximal end. The sheath extends into the middle palmar space, and the lumbrical canal upon its radial side communicates with the same area. In this relation it should be remembered that the lumbrical muscles do not lead into the thenar and middle palmar spaces directly, but lie just superficial to them, in

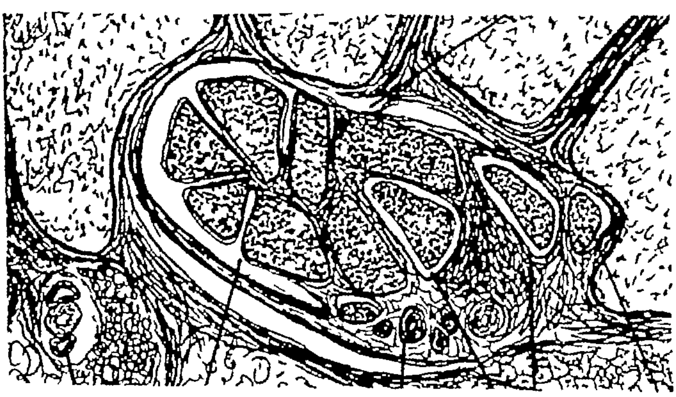


FIG 12 —Showing the relation of the tendons and synovial sheaths at the wrist Note in this drawing the four pockets in the ulnar bursa instead of three as commonly described, also the tendon sheath of the flexor pollicis longus and the accessory synovial sheaths (*SS*) See text for description of the difference between the relations of the tendons shown in Figs 10 and 12

a loft, as it were, from which pus easily extends into the space.

The ulnar bursa proper (Fig 11) begins at the proximal end of the finger sheath, spreads out rapidly and becomes a good-sized sac overlapping the metacarpal of the ring finger and the base of the middle metacarpal, passes under the transverse carpal ligament and extends a thumb's breadth above this, lying in relation to the lower end of the ulna and the ulnar side of the carpus and the radio-ulnar articulation, lying upon the pronator quadratus. It does not surround the tendons as a whole,

The Ulnar Bursa and the Sheath of the Tendon of the Little Finger.

The tendon sheath of the flexor tendon of the little finger communicates freely with the ulnar bursa in about

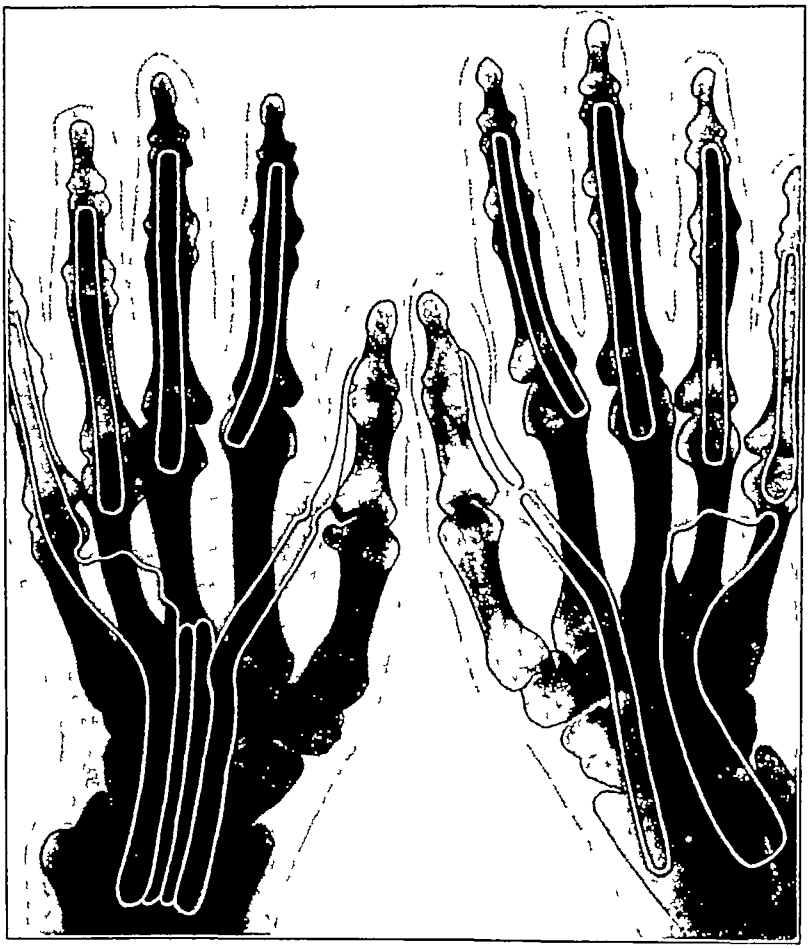


Fig 11 —Roentgen-ray picture upon which are shown two types seen in the flexor tendon sheaths Note that in the hand upon the left side there is a continuation between the little finger and the thumb and the ulnar bursa and radial bursa respectively Note also the connecting sheaths between In the hand upon the right side the bursæ are separated, not alone from their respective digital sheaths, but from each other The type noted upon the left side of the picture is present in almost all cases the author has seen, and surgery based upon this assumption will be the wiser course

one-half of the cases according to Poirier, but statistics vary somewhat on this point When the separation is

THE INTERCOMMUNICATION OF THE SHEATHS.

Poirier[1] discusses the communication between the bursæ as follows:

"The synovial sheaths of the palm have no communication with each other, and the authors cite in proof of this the case of Gosselin, who had observed it only once However, the result of my observation has been that this communication between the two important sheaths is very

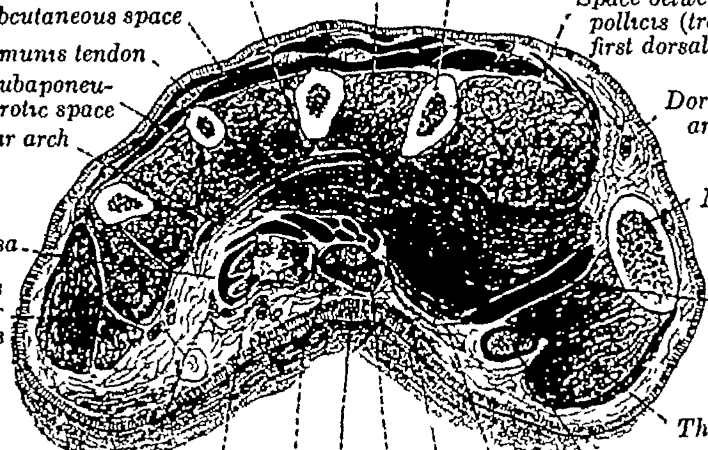


FIG 14 —Cross-section No VI Through distal part of thenar area

frequent in the adult. It is found in about one-half of the cases. The connection is made by a median synovial sheath which I will describe.

"Accessory synovial sacs: The writers call attention to the occasional existence of synovial sheaths in addition to the two large synovial sheaths, which they call accessory sheaths, found at times along the flexor tendons of the index finger. They lie between the ulnar and radial bursæ, being found especially along the deep tendon.

[1] P Poirier et A Charpy, Traité d'anatomie humaine, vol 2, p 189.

but lies to the ulnar side of the group of superficial and deep flexors and only envelops them as if they were pushed in along the outside. It follows, then, that the ulnar side of the sac is free while the radial side envelops the tendons, forming three spaces or arches, as it were, the most superficial between the aponeurosis and the superficial tendons, the middle between the superficial and deep tendons, and the third between the deep tendons and the carpal canal (Figs 8, 12, and 13). These all open upon the ulnar side into a common space This arrangement, first drawn attention to by Leguey, I believe, is in general true, but the arrangement varies at different levels and in different individuals, as can be seen by examining Fig 12, where there are four pockets, and none of them very deep Moreover, the tendons upon the radial side frequently have sheaths separate from the ulnar bursa, as well be mentioned under our fourth caption "The Intercommunication of the Sheaths" Attention should also be drawn to the fact that the superficial palmar arch with some of the unimportant branches of the ulnar nerve lies superficial to the sheath More important, however, is the fact that the sheath overlies the middle palmar space, making part of its roof, as it were (Fig 14).

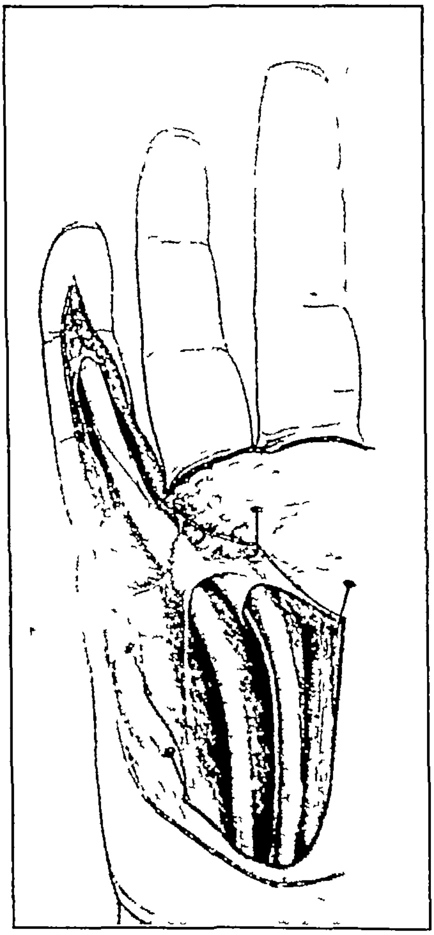


FIG 13 —Photograph after Poirier, in which the ulnar bursa has been opened, showing its extension into the little finger and its closure about the tendon of the ring finger



FIG 15 —A roentgen-ray picture of a cadaver hand in which the tendon sheaths have been injected with red lead The outline of the ulnar bursa and radial bursa with tendon prolongations is clearly shown Note the distance of the radial bursa from the metacarpal bone of the thumb and the relation of the ulnar bursa to the metacarpal bone of the middle finger

My researches show that these synovial sheaths are two in number They ought not to be called accessory, since one of these is almost always present I have named them the intermediary anterior and posterior palmar synovial sheaths.

"The intermediary posterior palmar sheath: This should be described as a normal sheath, since one finds it about eight times out of ten. It lies between the carpal canal and the flexor profundus of the index finger, and commences above the wrist at the edge of the radius. It spreads out at the level of the upper border of the lunate bone and goes down more or less on the tendon of the flexor profundus, varying from 3 to 8 cm To see it, it is necessary to cut transversely across the mass of muscles and tendons in the lower third of the forearm and turn the distal end down toward the fingers It is by the intervention of this sheath that the ulnar and radial bursæ communicate ordinarily.

"The anterior intermediary palmar sheath· This is found in hardly one-half of the cases Much smaller than the preceding, it is found placed between the superficial and deep tendons of the index finger.

"Both of these appear later than the others, and it is very rare to find them as completely organized In general, their walls lack the moist glassiness characteristic of complete development"

It is said[1] also that the synovial sheaths of the ring, middle, and index fingers communicate exceptionally with the ulnar bursa, following their respective tendons, occurring in the order of frequency as the fingers are named above I have had an opportunity to verify this observation in one case in which the tendon sheath of the ring finger communicated freely with the ulnar bursa Again, attention should be drawn to the fact that the

[1] Tillaxus, Traité d'anatomie topographique

5 to 6 cm in length and communicate with the sheath of the extensor pollicis longus through an oval opening by way of the longior (Poirier).

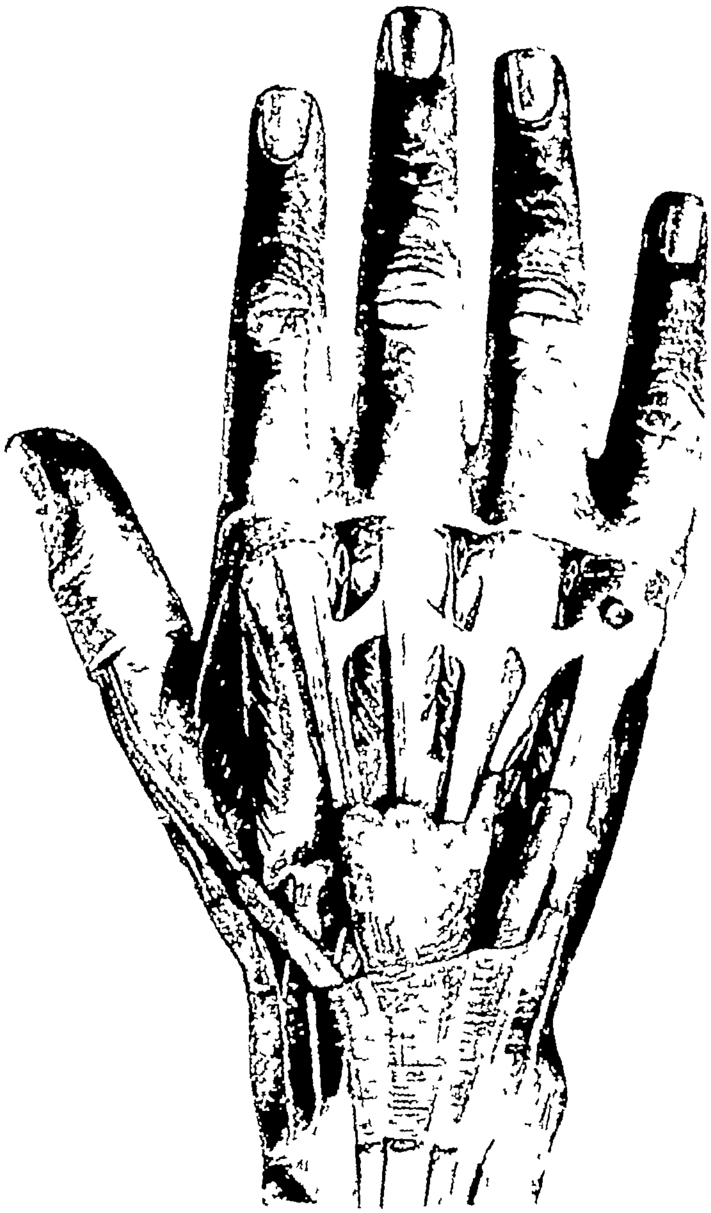


FIG 16 —Photograph from Bardeleben, showing tendons upon the back of the hand passing under the dorsal carpal ligament

3 Overlapping the above tendons, and communicating with them as described, we have the sheath of the extensor pollicis longus This is 6 to 7 cm in length

4 To the ulnar side of this we find the large sheath enclosing the tendons of the extensor digitorum communis

intermediary sheaths may differ from that type mentioned by Poirier I have dissected one case in which the profundus tendons of the index and middle fingers had separate sheaths. Communicating with the ulnar bursa (Fig 8) at this level the anterior intermediary sheath was absent, but 2 cm higher up the sheath of the middle finger profundus had disappeared, while the anterior and posterior intermediary sheaths were present (Fig 12). The communication, here, then, would have taken place as follows Ulnar bursa, sheath about the middle finger profundus, sheath about the index finger profundus, or posterior intermediary sheath, and, in this case apparently, anterior intermediary sheath, to the radial bursa. It can be seen that in a fulminating type of infection, such as a streptococcus involvement, the process would spread to the radial bursa, but in the more chronic types this devious course offers many chances for adhesive occlusion of the channel (Fig 12) This will be discussed later (see p 367) My clinical experience would seem to indicate that the intercommunication of the radial and ulnar bursæ is more common than stated by Poirier, at least infection spreads from the one to the other in a large majority of the cases in which one or the other is primarily involved.

THE SHEATHS UPON THE DORSUM

The synovial sheaths of the hand upon the dorsum are six in number These begin just above the dorsal carpal ligament and pass under and through it (Figs 9 and 16). They are found as follows

1. Lying upon the outer side of the styloid process of the radius, for the abductor pollicis longus and the extensor brevis pollicis They may have separate sheaths and are 5 to 6 cm. in length

2 Behind the styloid process, for the tendons of the extensor carpi radialis longus and brevis These are

CHAPTER IV

THE RELATION BETWEEN THE SYNOVIAL SHEATHS AND THE MAJOR FASCIAL SPACES.

A STUDY BY EXPERIMENTAL INJECTION OF THE OUTLINES, BOUNDARIES, AND DIVERTICULA OF THE MAJOR FASCIAL SPACES AND THE RELATION OF THESE TO THE SYNOVIAL SHEATHS

IN my desire to corroborate the findings by dissection in relation to the fascial spaces and tendon sheaths which have been detailed in the two preceding chapters, a large number of hands were injected after the manner described in Chapter II. The results obtained were most satisfactory, since they were so uniform that they absolutely fixed the boundaries and relations of the spaces and sheaths Moreover, these experiments gave results which, when applied clinically, were of inestimable value in determining the course an infection tends to pursue. Again, they determined not only the proper sites for opening any particular focus, but also indicated where secondary abscesses would be located, and thus facilitated early diagnosis and treatment of such extensions Furthermore, they demonstrated the relation between tendon-sheath abscesses and fascial-space abscesses. These studies have been of greater aid than any other in placing the treatment of infections of the hand upon a scientific basis

A brief outline of the various procedures will be of value in preserving a general picture This will be followed by a discussion of the individual experiments.

and the extensor indicis proprius It is 5 to 6 cm in length and terminates below in three prolongations The radial one encloses the communis tendon to the index finger and the extensor indicis proprius, the middle, the communis tendon to the middle finger, the one on the ulnar side covers the tendons to the third and fourth fingers

5 One opposite the interval between the radius and ulna, for the extensor digiti quinti proprius This is longer than the others, being 6 to 7 cm in length Covering the upper one-third of the length of the third interosseous space, it may bifurcate below, following the two branches of the tendon

6 Upon the back of the ulna, the synovial sheath of the tendon of the extensor carpi ulnaris This is 4 to 5 cm in length

From the tendon sheath of the index finger, Experiments 8, 9, 27, and 35.

From the tendon sheath of the thumb, Experiments 10 to 17.

II The boundaries and diverticula of the major fascial spaces.

(*a*) Middle palmar space.

Injection *via* ring finger tendon sheath, Experiments 3, 4, 18 to 20.

Injection *via* middle finger tendon sheath, Experiments 1 and 2

Injection *via* little finger tendon sheath, Experiments 5, 6, 7, and 47.

Injection *via* palmar fascia, Experiments 21 to 25.

Injection *via* lumbrical muscle space, Experiments 26*A* and 26*B*

Of these, great force was used in 19, 20, and 3 From these and others, deductions were made as to the location of pus extensions from the middle palmar space.

(*b*) Thenar space

Injection *via* index finger sheath, Experiments 27 to 35, 8 and 9

Injection *via* palmar fascia, Experiments, 36, 37, and 38

Of these, great force was used in the experiments from 27 to 35 inclusive, and from the results deductions were made as to the location of pus extensions from the thenar space

(*c*) Dorsal subcutaneous space

Injection between first and second metacarpals, Experiments 39 and 40.

Injection between second and third metacarpals, Experiments 41 and 42

(*d*) Dorsal subaponeurotic space

Experiments 43, 44, and 45

(*e*) Hypothenar space

General results of experiments quoted

(*f*) Major forearm space.

Our first group of experiments had for its object the determination of the relation of rupture of the synovial sheaths to the secondary abscesses in the fascial spaces. In other words, if an infection began in a particular tendon and ruptured from it, where would the secondary abscess lie? This was determined by an extensive series of experiments upon each sheath Clinical evidence has accumulated in my hands sufficient to verify every one of the experimental deductions we have here made

The second problem dealt with determining the boundaries and diverticula of each of the major spaces I have described To do this, injections of these spaces were made from every possible source of infection—the tendon sheaths, direct implantation, and extension from neighboring spaces The results were uniform, as will be seen by a study of the experiments.

In the third group injections were made with great force to determine where pus would extend when it ruptured from these major spaces

By these experiments we have determined, for the synovial sheaths, the sites of extension, and for each fascial space, (*a*) the source of involvement, (*b*) the normal limitations of that space, (*c*) the areas to which pus will extend from the space Here again clinical evidence will be later adduced to show that all of these deductions are pathologically correct

For the sake of clearness a tabulation of these experiments is appended

I. The relation of rupture of the tendon sheaths to the fascial spaces.

From the tendon sheath of the middle finger, Experiments 1 and 2

From the tendon sheath of the ring finger, Experiments 3, 4, 18, 19, and 20.

From the tendon sheath of the little finger, Experiments 5, 6, 7, and 47

Experiment 1.—Left hand Cannula inserted into tendon sheath of middle finger at the middle of the proximal phalanx, moderate force used in injection. The mass occupied the middle palmar space, going up to about ½ inch distal to the annular ligament. Distalward it had returned along the lumbrical muscles of the little and ring fingers nearly to the web of the fingers. It did not return to any extent along the lumbrical muscle of the middle finger In every way this was a perfect representation of what is probably a typical collection in the middle palmar space (See experimental injection drawing, Fig 17)

Experiment 2—Left hand. Same as No. 1 in every particular No mass to radial side of middle finger.

Experiment 2A.—Right hand. Same as No. 1 in every particular.

INJECTION VIA THE TENDON SHEATH OF THE RING FINGER.

The tendon sheath was opened at the base of the finger and the cannula inserted into the sheath and pushed through the proximal blind end into whatever space was at that site, thus trying to demonstrate where an infection would spread to if it extended from the tendon sheath In one case, which is not included in the report, the tendon sheath did not end blindly, but extended up into the group of tendons at the wrist In every case where the sheath ended normally the mass filled the middle palmar space

Experiment 3*A*—Left hand. Moderate force used In this case the mass occupied the middle palmar space as it has been described No diverticula were noted except that the mass extended along the lumbrical muscle of the ring finger for about ½ inch (See experimental injection drawing, Fig 18)

Experiment 4—Right hand Moderate force used In this case the cannula broke from the blind end, evi-

Injection *via* flexor pollicis longus sheath, Experiments 46, 10 to 17

Injection *via* ulnar bursa and little finger, Experiments 47 and 50

Injection *via* middle palmar space, Experiment 49.

Injection along radial and ulnar vessels, grouped under composite Experiment 51

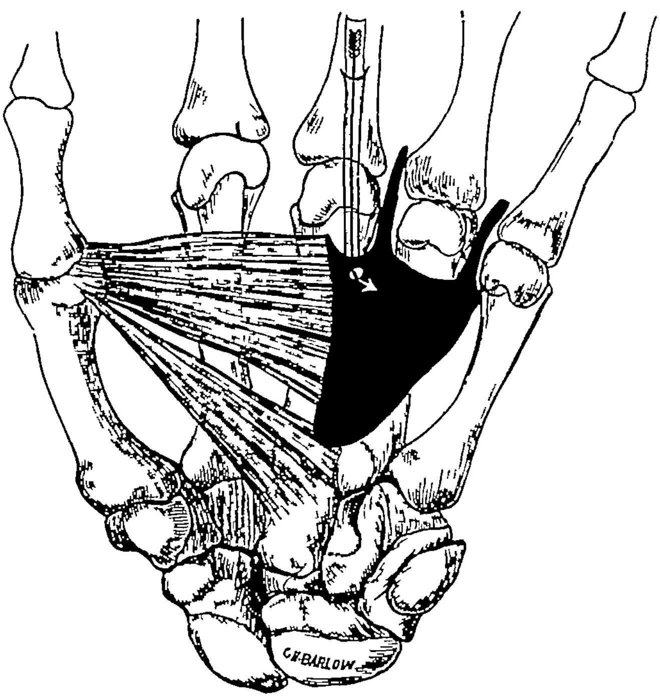


FIG 17 —Schematic drawing made from a dissection of a hand injected from the tendon sheath of the middle finger The mass filled the middle palmar space and extended along the two lumbricals

THE RELATION OF TENDON SHEATH RUPTURE TO THE MAJOR FASCIAL SPACES

INJECTION VIA THE TENDON SHEATH OF THE MIDDLE FINGER

In inserting the cannula no effort was made to reach any particular spot, but the injection mass was allowed to rupture through the weakest spot in its course It will be noted that in each instance the mass entered and filled the middle palmar space

dently superficial to the tendon, for there was a small mass only, lying superficial to the tendon, about ¼ inch wide and ¾ inch long. It had not involved the middle palmar space, but it should be noted that the amount injected was small and examination showed the thinnest wall was in relation to that space, and in case of infection the pus would have extended into it in all probability Experiments 18, 19, and 20 support this assumption and clinical cases prove that in any extension from the tendon sheaths of the index, middle or ring fingers, the pus quickly passes from this area of loose connective tissue into the thenar or middle palmar spaces Therefore, in a clinical sense, we may say that in rupture from these sheaths the pus passes into these major spaces The indefinite connective tissue spaces about the tendons, nerves and bloodvessels superficial to the middle palmar space are in no sense major spaces, nor of great clinical significance It is, however, in this loose connective tissue that pus lies in those infrequent cases where we have a primary necrosis of the palmar fascia (See experimental injection drawing, Fig 19)

Injection via the Tendon Sheath of the Little Finger

Experiments 5 and 6 demonstrate where the pus will lie in those cases in which the rupture takes place in the hand, namely, the middle palmar space. It may also rupture in the forearm In fact, that is its most frequent site The location of the pus in the latter case will be seen by studying Experiment 47.

Experiment 5—During an attempt to inject the ulnar sheath in the right hand it was found to be obliterated at the level of the phalango-metacarpal articulation The cannula broke out into a space which was injected with moderate force, and upon dissection the middle palmar

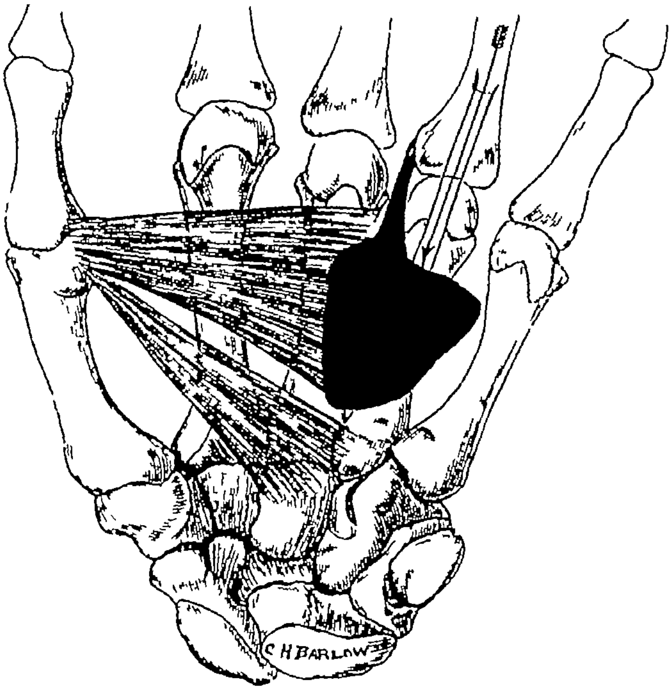


FIG 18 —Schematic drawing made from a dissection of a hand injected along the tendon sheath of the ring finger The mass filled the middle palmar space, with extension along the lumbrical muscle

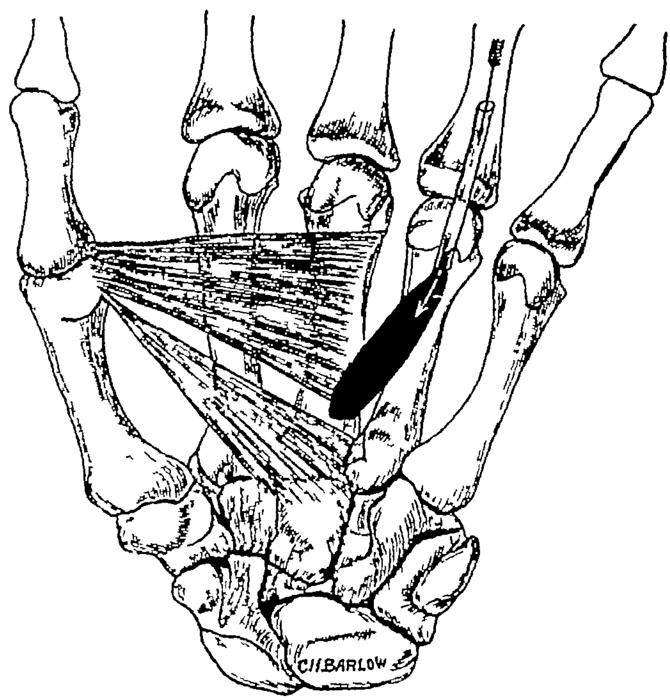


FIG 19 —Schematic drawing made from a dissection of a hand in which the mass was injected from the tendon sheath of the ring finger and filled the loft of loose connective tissue over the middle palmar space, but did not rupture it

space, as already described, was found filled with the mass It had not extended under the transverse carpal ligament, into the thenar or hypothenar areas, but had returned along the lumbrical muscles of the little, ring, and middle fingers (See experimental injection drawing, Fig 20)

Experiment 6 —In another attempt to inject the ulnar bursa with moderate force, the injection was arrested at the transverse carpal ligament owing to the rigidity of the tissue of the subject. Due to this fact and the friability of the tissues incident to age, the ulnar bursa ruptured at about the middle of the palm, and the mass was found to occupy the middle palmar space only, in addition to the ulnar bursal sheath of the tendons The mass returned along the ring finger lumbrical only The surgical importance of this experiment is readily seen (See experimental injection drawing, Fig 21)

Experiment 7.—Here we have the result produced in those cases in which the rupture is in the forearm and not in the hand The roentgen-ray photograph here presented, which is made from the hand injected in Experiment 7, presents a clear picture of the bones in their relation to the injected bloodvessels and ulnar bursa (Fig 22) Upon this plate have been placed lines which represent the boundaries of the thenar and middle palmar spaces The numerous parallel lines at the distal end of the palm represent the dense tissue here overlying the articulation, in which there are no spaces except those made by the lumbrical muscles with the vessels and the synovial sheaths (See cross-section, Fig 5) Three curved lines show the position of the flexion creases of the palm of the hand, and in relation to these, note that the proximal end of the distal flexion crease corresponds with the beginning of the dense tissue noted Again, note that the distal end of the middle flexion crease also begins at the dense tissue, and hence a line drawn between

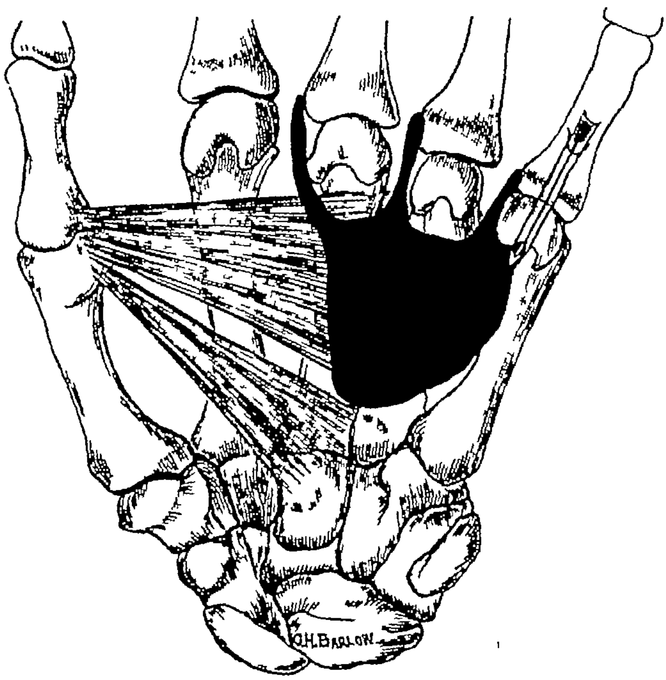


FIG 20 —Schematic drawing made from a dissection of a hand injected from the tendon sheath of the little finger with which the ulnar bursa did not connect The mass ruptured into the middle palmar space, filling it, with prolongations along three lumbrical muscles

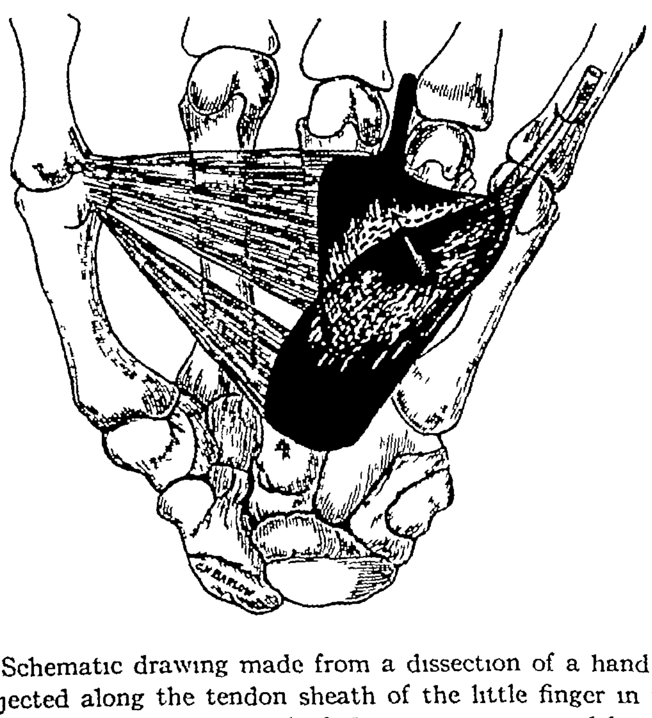


FIG 21 —Schematic drawing made from a dissection of a hand in which the mass was injected along the tendon sheath of the little finger in which closure of the ulnar bursa at the upper end of the transverse carpal ligament favored rupture from the ulnar bursa, the mass filling the middle palmar space, with extension along one lumbrical muscle.

these two points limits the palmar spaces distally. Pay particular attention to the point at which the middle flexion crease crosses the space between the metacarpal bones of the middle and ring fingers, at the distal end of the middle palmar space An incision here would avoid the thenar space upon the radial side, the ulnar bursa upon the ulnar side, the dense tissue distally, and the deep palmar arch (*A*), which is seen crossing the upper part of the middle palmar space proximally Note that although the injection mass has broken from the ulnar sheath into the forearm, yet the spaces in the hand are uninvolved

In Experiment 47, as in many other experiments not here reported, the mass ruptured in a similar manner at the proximal end of the sheath under the flexor profundus tendons in the arm This is the most common site of extension from the ulnar bursa. (See Experiment 47 for a complete description of these cases)

Injection via the Tendon Sheath of the Index Finger.

Here the findings are positive. In addition to the experiment here detailed, many others were performed which gave the definite information that when pus ruptures from this sheath it enters the thenar space

Experiment 8 —Injection was made through the tendon sheath of the index finger The mass occupied the thenar space, did not go into the forearm or middle palmar space Passed around the lower or distal edge of the adductor pollicis (transversus), filled a space the size of a walnut between that muscle and the first dorsal interosseous, and abutted on the dorsal subcutaneous tissue at web. It followed the index lumbrical only (See experimental injection drawing, Fig 23)

Experiment 9 —Same findings as in Experiment 8

Experiments 27 to 35 corroborate these findings



FIG 22 —Roentgen-ray picture, showing the boundaries of the thenar and middle palmar spaces (*M P S*) marked and the proper site for opening the latter indicated (•) The ulnar bursa and bloodvessels are injected (see Exp 7) *A*, artery, *B*, thenar space, *M P S*, middle palmar space

Experiment 10 —A cannula was inserted into the sheath of the flexor pollicis longus at the thumb The injection mass was found to have filled completely the radial bursa, including the part proximal to the transverse carpal ligament The mass had ruptured from the proximal end and passed up into the forearm No extravasation had taken place into the hand, either by direct rupture or retrograde extension The attachment of the flexor pollicis longus at its origin had been torn in part from the bone The mass extended up along this muscle on the radial side of the forearm, having on its ulnar boundary and roof the flexor digitorum profundus and the flexor digitorum sublimis The major portion of the mass was found under the flexor digitorum profundus, going over even to the flexor carpi ulnaris. It filled an area extending from the wrist-joint to within 3 inches of the elbow-joint.

Experiment 11.—The findings here were practically the same except that a small part of the mass passed downward under the transverse carpal ligament and the ulnar bursa to fill partially the middle palmar space. This, however, would probably not occur in an inflammatory lesion owing to the small channel present

Experiment 12 —In this case the mass ruptured from the upper third of the synovial sheath, just distal to the transverse carpal ligament It extended downward to the thenar space and partially filled it. A small part had also entered the upper end of the palmar space, owing to the indefinite septum separating these spaces at the upper end The large mass, however, was in the thenar space, but it demonstrated that extension into the middle palmar space would be possible in neglected cases

Experiments 13, 14, 15, *and* 16 —These were practically duplicates of the above results.

Experiment 17 —In this hand there was apparently a free anatomical communication between the ulnar

Injection via the Tendon Sheath of the Flexor Pollicis Longus

Here one would expect the mass to enter the thenar space in the hand, and we were therefore surprised to find that this was not generally the case To determine this point definitely, eight experiments were made. In each case great pressure was used in the injection The

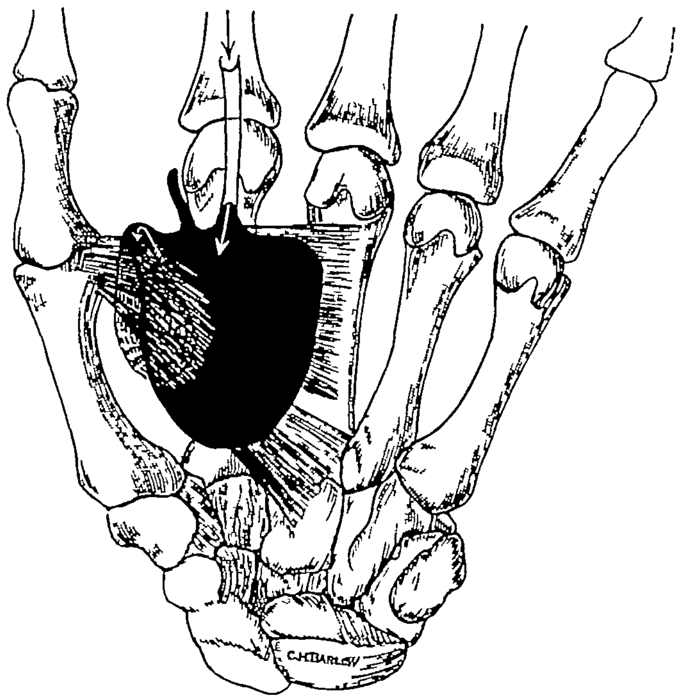


Fig 23 —Schematic drawing made from a dissection of a hand injected along the tendon sheath of the index finger Mass filled thenar space and extended around to the dorsum distal to the adductor pollicis (transversus) and also along the lumbrical muscle

cannula was inserted into the tendon sheath in the thumb and so bound that the mass could not escape around the needle These experiments showed that in a majority of cases the rupture took place into the forearm under the flexor digitorum profundus It did at times, however, rupture distal to the transverse carpal ligament and fill the thenar and even the middle palmar spaces.

THE NORMAL BOUNDARIES OF THE MAJOR FASCIAL SPACES AND THE POSITION OF SECONDARY ABSCESSES IN CASES OF EXTENSION FROM THESE SPACES.

THE MIDDLE PALMAR SPACE.

INJECTION VIA THE TENDON SHEATH OF THE RING FINGER —*Experiment* 18.—Left hand, along tendon sheath of ring finger, the mass was injected with considerable force The middle palmar space as described was filled Thenar and hypothenar areas were free. The mass followed along the little and ring finger lumbricals for ¾ inch, none along other fingers, none through between bones to back, but it did extend under the tendons, up into forearm, where a large mass was found lying under the deep muscles upon the pronator quadratus and the interosseous septum up to the pronator teres The mass came to the surface late upon the radial side, about 2 inches above the wrist, but the mass was most marked upon the ulnar side from above downward, between the flexor carpi ulnaris and the deep tendons and muscles The importance of the position of this mass from a clinical standpoint can be seen While anatomically this extension into the forearm can occur it should be emphasized that it is extremely uncommon in infections due to the obliteration of the canal at the wrist by inflammatory adhesions

Experiment 19—Same findings as in Experiment 18

Experiment 20—Wrist bound tightly above transverse carpal ligament, cannula inserted along ring finger synovial sheath, and mass injected with great force, the idea being to see where the mass would rupture in case that means of exit was closed. None of the mass went to the forearm or dorsum, but did rupture into the thenar space at the upper or proximal end of the intervening septum and filled the thenar space, passed along all lumbrical muscles into the canals for a considerable distance, but

and radial bursæ, for the mass filled the ulnar bursa There was also an extension into the forearm from a rupture of the proximal end at the radial bursa.

General Deductions as to Relation of Tendon Sheaths to Major Fascial Spaces

The injections through the synovial sheaths of the tendons of the ring and middle fingers passed into the middle palmar space, while that space was reached also from the little finger in those cases where the synovial sheath was separated from the ulnar bursa, and, indeed, the contents of the ulnar bursa itself, when it ruptured into the palm, entered the same space When the injected mass was small in amount and inserted with moderate force it might lodge temporarily in the loose connective tissue superficial to the middle palmar space, but with slightly added force it passed into the latter space. Injection masses from the index synovial sheath passed into the thenar space In those cases where the synovial sheath of either of these fingers communicated with the ulnar bursa, the mass passed into that, and followed the course of the bursal injections The extreme rarity of communication between the index synovial sheath and the ulnar bursa should be borne in mind

A mass from the radial bursa or the synovial sheath of the flexor pollicis longus, if it ruptures into the hand, will lie in the indefinite spaces mentioned as lying about the muscles of the metacarpal bone of the thumb and passed from these into the thenar space It is possible for the sheath to erode into the thenar space, but the pus is more likely to rupture into the fascial spaces of the forearm and lie under the flexor digitorum profundus The ulnar bursa may rupture into the middle palmar space and it will almost surely rupture into the forearm under the flexor digitorum profundus

metacarpal space between ring and middle fingers. Moderate force used.

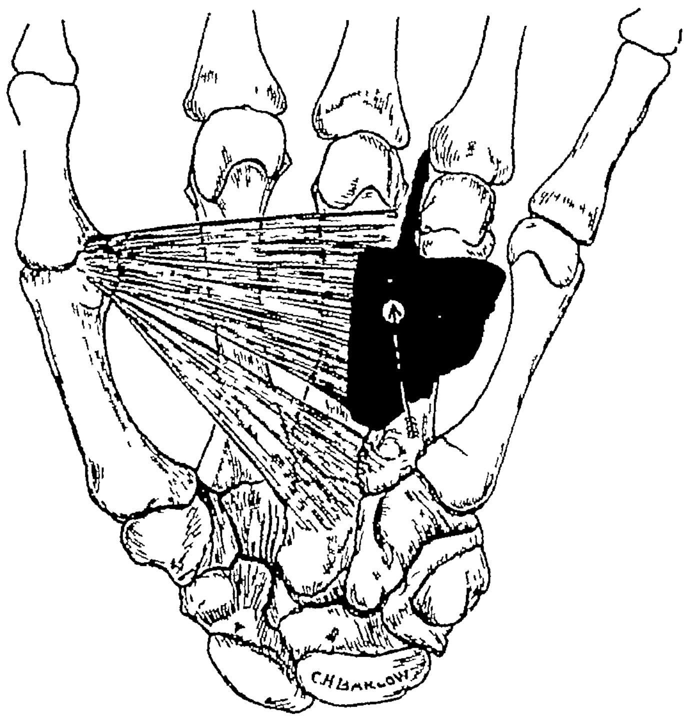


FIG 25 —Schematic drawing made from a dissection of a hand in which the injection was made through the palmar fascia into the middle palmar space The mass filled the middle palmar space, with extension along one lumbrical muscle

NOTE.—Care must be taken that the cannula goes dorsal to the tendons, *i e*, really into space, otherwise the mass will be confined to the imperfect spaces around the tendons, particularly superficial to them. Even if this should occur, if great force is used, it will rupture into the great space; not so readily, however, as would pus, since the erosive action of the latter is not present in simple injections.

Upon dissection the mass was found to be limited to what we have found to be the middle palmar space. It was limited upon the radial side by the attachment of fascia to the middle metacarpal bone This was the long leg of the right-angle triangle. The ulnar side

not out into the web between the fingers. This extension, however, did occur in Experiment 31. (See experimental injection drawing, Fig. 24)

Experiments 3 and 4 corroborate these findings.

Experiments, 1, 2, and 3, in which the space was injected from the middle finger, and Experiments 5 and 6, in which the space was injected from the little finger, present the same findings as in Experiments 18, 19, and 20.

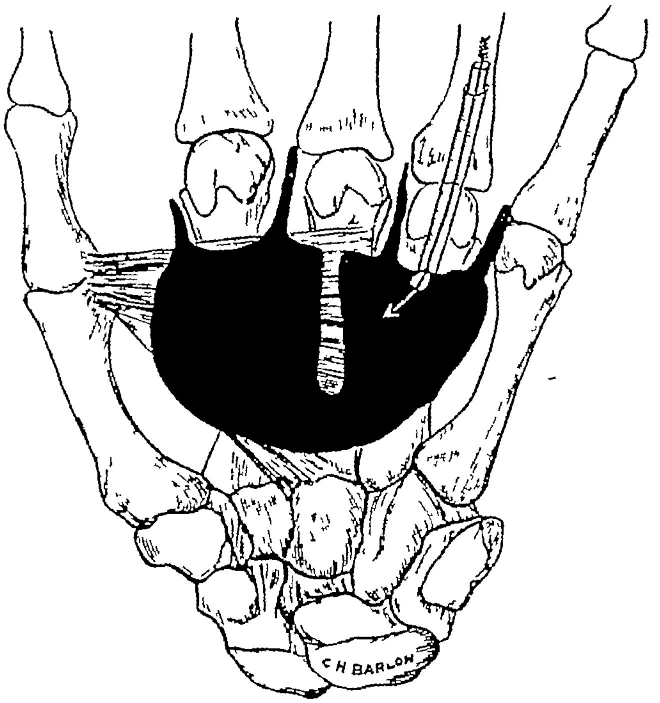


FIG 24 —Schematic drawing made from a dissection of a hand in which the injection was made along the tendon sheath of the ring finger under great force The mass filled the middle palmar and thenar spaces, with extension along all lumbrical muscles

INJECTION THROUGH THE PALMAR FASCIA INTO THE MIDDLE PALMAR SPACE —Injection of the space by inserting a needle through the palm directly into the space gives the results uncomplicated by any other process.

Experiment 21.—Left hand. Cannula inserted through the palmar fascia where middle flexion crease crosses

metacarpal space between ring and middle fingers. Moderate force used.

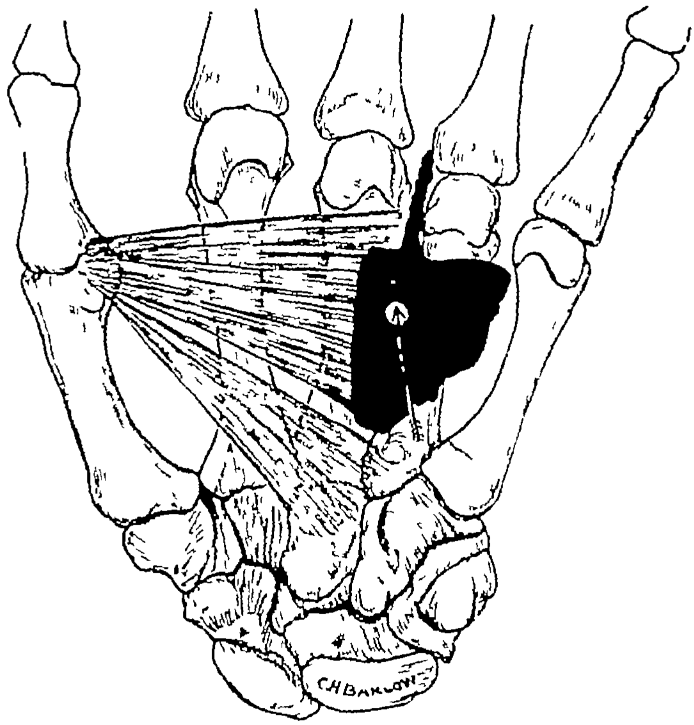


FIG 25 —Schematic drawing made from a dissection of a hand in which the injection was made through the palmar fascia into the middle palmar space The mass filled the middle palmar space, with extension along one lumbrical muscle

NOTE.—Care must be taken that the cannula goes dorsal to the tendons, *i. e.*, really into space, otherwise the mass will be confined to the imperfect spaces around the tendons, particularly superficial to them. Even if this should occur, if great force is used, it will rupture into the great space; not so readily, however, as would pus, since the erosive action of the latter is not present in simple injections.

Upon dissection the mass was found to be limited to what we have found to be the middle palmar space. It was limited upon the radial side by the attachment of fascia to the middle metacarpal bone. This was the long leg of the right-angle triangle. The ulnar side

represented the hypotenuse of the triangle lying to the radial side of the hypothenar space. The apex of the triangle, or the highest point to which the mass spread, was about 1 inch distal to the distal flexion crease of the wrist, or about a finger's breadth proximal to a line drawn transversely across the palm from the web of the extended thumb.

At the lower part of the palm, *i e*, toward the web of the fingers, the greater part of the mass was limited by a line drawn between the radial end of the middle flexion crease and the ulnar end of the distal flexion crease of the palm, or, roughtly speaking, about a thumb's breadth above the web of the fingers, this is the short leg of our right-angle triangle A prolongation of the mass had taken place, however, along the lumbrical muscle between the middle and ring fingers, going almost to the web of the fingers There was no appreciable mass along the other lumbrical muscles, although some of the stain from the methylene blue used in the injection mass had stained the space around the muscle leading to the little finger. No other prolongations were present It did not break into the interosseus muscles or superficially about the tendons Superficial palmar vessels crossed the upper part of mass (See experimental injection drawing, Fig. 25)

Experiment 22 —Left hand Injection at the same point and in the same manner as No. 21 The mass here occupied exactly the same area of distribution as in Experiment 21, except the mass as a whole was not so large, being a little larger than an almond The most prominent part of the mass was in the middle of the palm, over the middle metacarpal space There were slight prolongations distally along the lumbrical muscle between ring and middle metacarpals as above

Experiment 23 —Injection made same as in Experiment 21 Both roentgen-ray picture and dissection made of this right hand Mass extended somewhat higher in

the hand than in Experiment 21, going to a point about a finger's breadth below, *i e.*, distal to the distal flexion crease of the wrist lying dorsal to the tendon group, laterally its boundaries were the same, while at the distal portion of the palm a prolongation of the mass occurred along the lumbrical muscles going to the little, ring, and middle fingers This is of considerable importance, since it is remembered that the relation of the lumbrical muscle of the middle finger to the middle palmar space was discussed in the division devoted to cross-sections, and this experiment bears out the assumption hazarded there that this muscle space was really a diverticulum of the middle palmar space and not of the thenar space. (See cross-sections, Figs 6 and 7.)

Experiment 24. — Injection left hand, same as in Experiment 21. Mass occupied same space as Experiment 21, except that the mass spread down along the lumbrical muscle of the little and ring fingers for a distance of ⅓ inch.

Experiment 25 (see roentgen-ray photograph, Fig 26) — This hand was also dissected. It demonstrates how the mass extends down along the lumbrical muscles, and shows also what site should be opened to evacuate the contents of the space. Note that the hypothenar and thenar regions are uninvolved, the mass not extending to the radial side of the middle metacarpal. It is seen that the ulnar bursa would lie over the ulnar side of the mass

INJECTION ALONG LUMBRICAL MUSCLE OF RING FINGER. —*Experiment* 26*A* —Cannula inserted along lumbrical muscle, left hand Some difficulty was experienced in the insertion, but when successful the mass occupied the middle palmar space There was no return along the lumbrical muscles Moderate force used in injection. (See experimental injection drawing, Fig 27)



FIG 26 —Roentgen-ray plate made from a hand in which the middle palmar space was injected with a mixture of red lead and plaster of Paris Photograph represents location of pus in typical middle palmar space infection

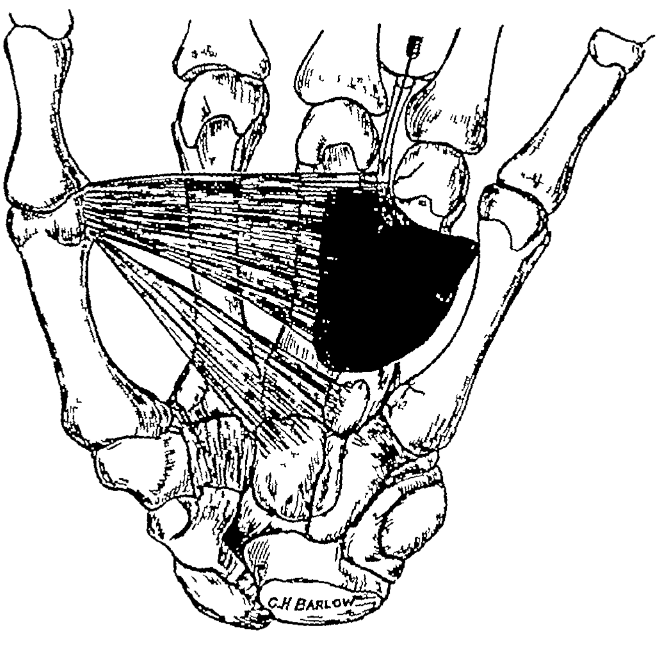


FIG 27 —Schematic drawing made from a dissection of a hand in which the injection was made along the lumbrical muscle space between middle and ring fingers Middle palmar space filled

Experiment 26B.—Right hand. Same technique, injection mass lies along lumbrical muscle. Middle palmar space only partly filled.

The Thenar Space.

Note.—The first injections of this space were very unsatisfactory, owing to two errors in technique, which were corrected later. In the first place, the injections were not made deep enough, and secondly, they were too far to the radial side over the thumb It is true that the results obtained by these injections were instructive in that they served to show indefinite limited spaces at these sites, but they did not reach the large spaces under consideration.

Injection via the Tendon Sheath of the Index Finger.—*Experiment 27.*—Left hand. Cannula inserted into tendon sheath about middle of proximal phalanx and ruptured from sheath at its proximal end. Moderate force used in injection The mass when dissected out showed the limitations of the thenar space as described The mass passed up dorsal to the tendon, to a thumb's breadth below the transverse carpal ligament It did not go to the ulnar side of the middle metacarpal. The mass laid directly upon the adductor pollicis (transversus) It did not go along the lumbrical muscle to the side of the index finger. It did not spread around under the web of the thumb to the dorsum of the hand, but was limited at the distal border of the adductor pollicis (transversus) It did spread to the back, however, at the upper or proximal edge of the adductor pollicis (transversus), going between the adductor pollicis (transversus) and the adductor pollicis (obliquus), thus lying between the adductor transversus and the first dorsal interosseus at the distal edge of which it came to lie in the subcutaneous tissue of the dorsum (See experimental injection drawing, Fig 28)

Experiment 28—Injection same as Experiment 27. Here the mass did not fill the space completely, but did return along the lumbrical muscle to the radial side of the index finger, condition well marked For clinical purposes, Experiments 27 and 28 should be studied together The probability is that the cannula did not rupture entirely into the space, but did get out of the

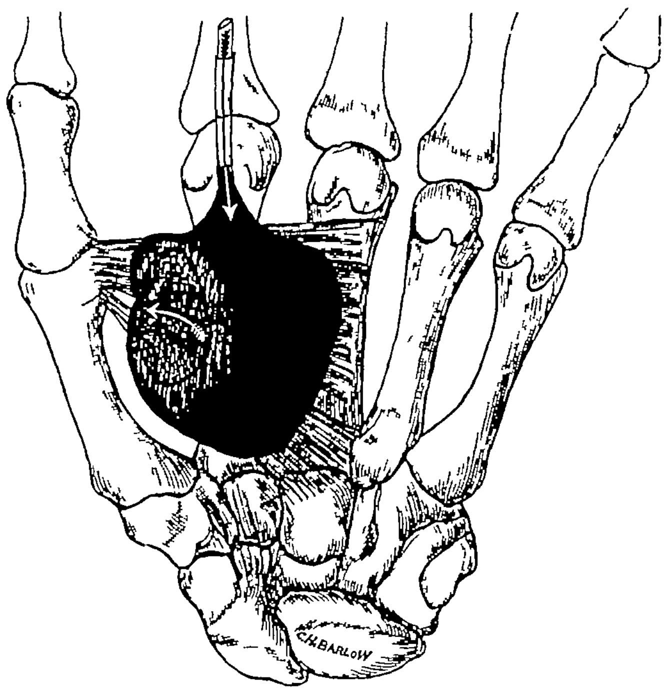


FIG 28—Schematic drawing made from a dissection of a hand in which the injection was made along the tendon sheath of the index finger Mass filled thenar space and extended to dorsum between adductor pollicis (transversus) and adductor pollicis (obliquus)

synovial sheath into the indefinite spaces in the loose connective tissue about the tendon above the thenar space (See experimental injection drawing, Fig 29)

INJECTION OF THE THENAR SPACE UNDER FORCIBLE PRESSURE—The index synovial sheath was opened and cannula forced out of the proximal end into the palm, forcible pressure with force pump was maintained for from three to five minutes. Owing to the fact that the

routes of extension from the thenar space were somewhat difficult to determine accurately, nine injections of the space were made, with the following results: In none of the cases did the mass go up into the forearm In 3 cases only did it go into the middle palmar space. In 8 cases the mass passed dorsal to the adductor pollicis (transversus), of these, in 6 the mass went to the dorsum between the adductor pollicis (transversus) and the

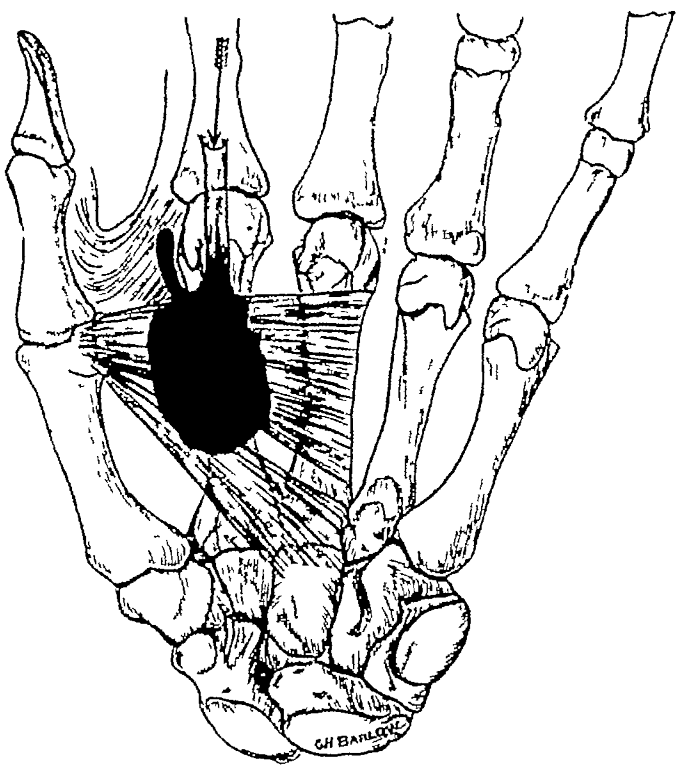


FIG 29 —Schematic drawing made from a dissection of a hand in which the injection was made along the tendon sheath of the index finger Mass filled the thenar space and extended along the lumbrical muscle

adductor pollicis (obliquus), and in 4 passed below or distal to the adductor pollicis (transversus) to lie between it and first dorsal interosseus. In no case did the mass pass to the dorsum between the second and third metacarpals.

Experiment 29—Left hand. Tissues well preserved, mass here occupied thenar space, and spread between the transverse and oblique heads of the adductor pollicis

Experiment 28.—Injection same as Experiment 27 Here the mass did not fill the space completely, but did return along the lumbrical muscle to the radial side of the index finger, condition well marked For clinical purposes, Experiments 27 and 28 should be studied together. The probability is that the cannula did not rupture entirely into the space, but did get out of the

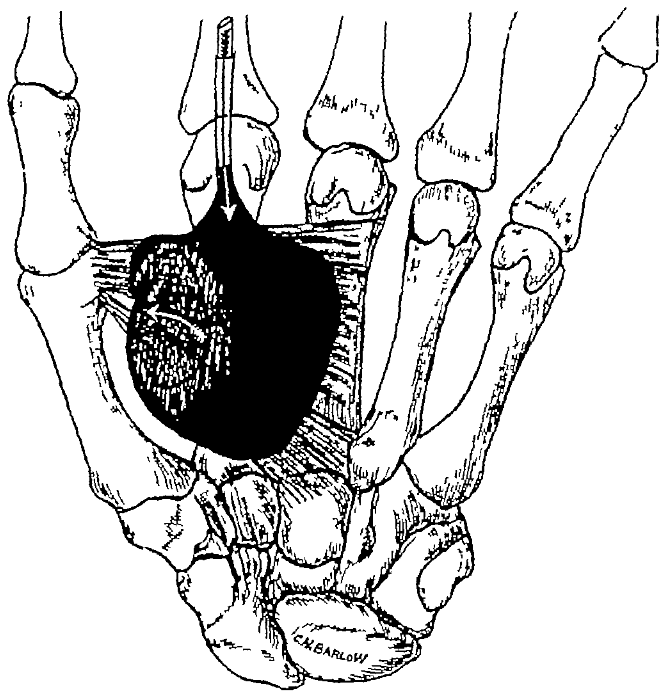


FIG 28 —Schematic drawing made from a dissection of a hand in which the injection was made along the tendon sheath of the index finger Mass filled thenar space and extended to dorsum between adductor pollicis (transversus) and adductor pollicis (obliquus)

synovial sheath into the indefinite spaces in the loose connective tissue about the tendon above the thenar space. (See experimental injection drawing, Fig. 29.)

INJECTION OF THE THENAR SPACE UNDER FORCIBLE PRESSURE —The index synovial sheath was opened and cannula forced out of the proximal end into the palm, forcible pressure with force pump was maintained for from three to five minutes Owing to the fact that the

and illustrated by Fig. 188. (See experimental injection drawing, Fig. 30.)

Experiment 33—This mass extension was extremely interesting. It filled the thenar space and then passed to the space between the adductor pollicis (transversus) and the first dorsal interosseus, going both above and below on the adductor, *i. e.*, both proximal and distal,

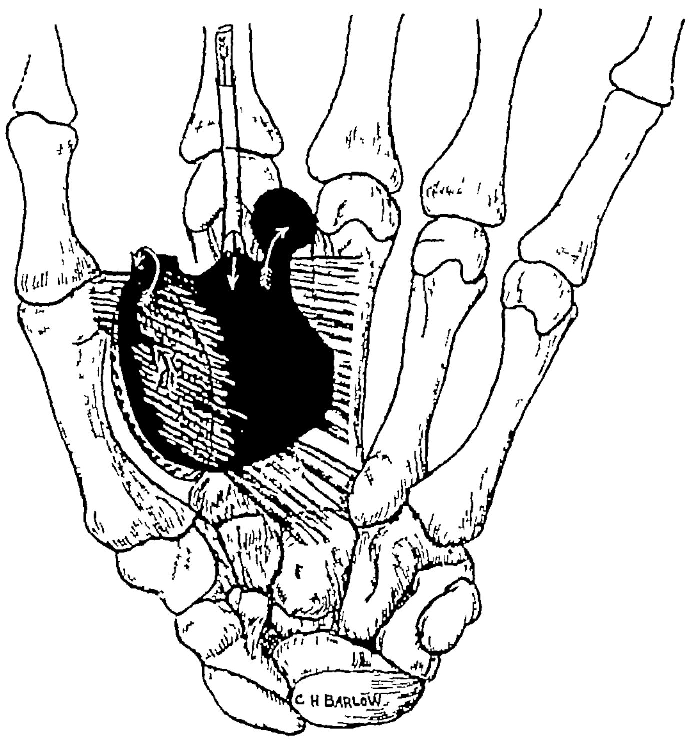


FIG 31—Schematic drawing made from a dissection of a hand in which the injection was made along the tendon sheath of the index finger The mass filled the thenar space, extended to the dorsum below the adductor pollicis (transversus) and to the palm through a defect of the palmar fascia

abutting on the dorsal subcutaneous tissue at web at distal edge of first dorsal interosseus, extending along index lumbrical canal, and did not go into middle palmar space or forearm The most interesting extension, however, was that which occurred through the palmar aponeurosis at the distal edge of the bases of the index and middle fingers into the soft pad of fatty tissue which lies here in the palm, thus explaining the infrequent cases

to fill space size of a walnut between them and first dorsal interosseus, also ruptured through tissues between thenar space and middle palmar space at the proximal end of the septum, passed over to fill the middle palmar space, and accompanied the four lumbricals into their respective canals Did not go under tendons to forearm

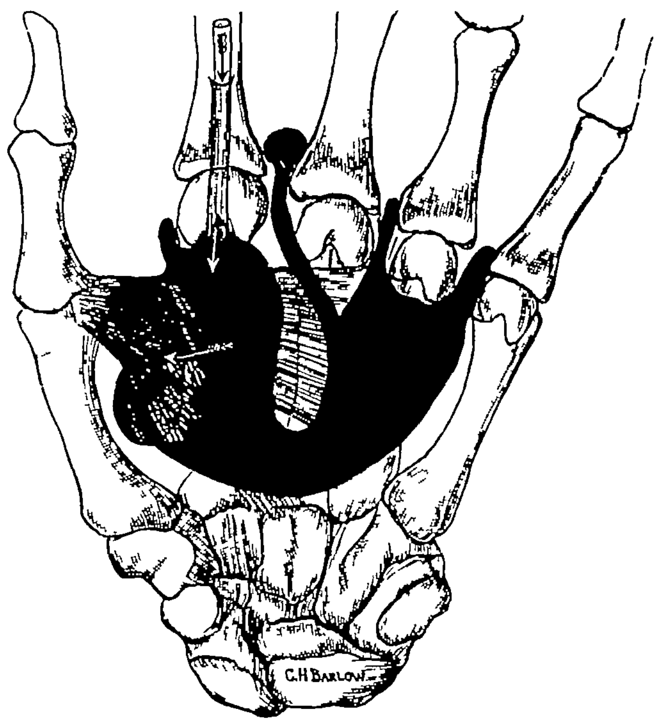


FIG 30 —Schematic drawing made from a dissection of a hand in which forcible injection was made along the tendon sheath of the index finger Mass filled the thenar space and extended over to the middle palmar space, along all the lumbrical muscles, and went to the dorsum, first between the transverse and oblique heads of the adductor pollicis, and secondly between the index and middle fingers (See Fig 188 for explanation of this latter extension)

Experiments 30, 31, and 32 were the same as Experiment 29, except that the mass in 32 did not invade the middle palmar space All went above the adductor pollicis (transversus) to dorsum, however The mass in 31 passed along the middle finger lumbrical and came to lie in the tissue of the web immediately beneath the web. The anatomical explanation of this latter extension is given in the study of the cross-sections in Chapter II

the subcutaneous tissue. The space filled corresponded to the area comprised between the adduction crease of the thumb and the metacarpal bone of the thumb in adduction (See experimental injection drawing, Fig. 32.)

Experiment 37.—Attempt to inject thenar space. Left hand. Cannula was inserted too far to radial side over muscular groups Small mass was found in indefinite

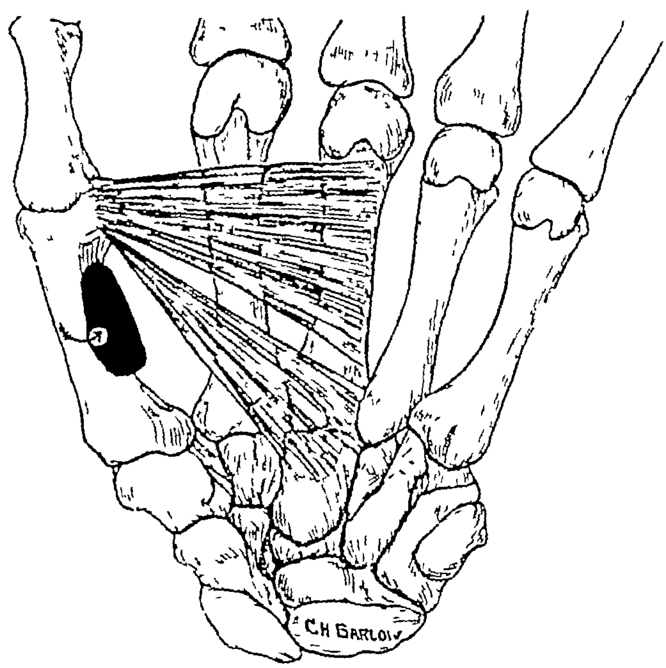


FIG 33 —Schematic drawing made from a dissection of a hand in which an attempt was made to inject the thenar space but in which the cannula reached only one of the indefinite spaces near the metacarpal bone

space adjacent to flexor pollicis brevis (See experimental injection drawing, Fig 33)

Experiment 38 —Same as Experiment 37.

THE DORSAL SUBCUTANEOUS SPACE.

INJECTION OF SUBCUTANEOUS TISSUE OF THE DORSUM BETWEEN THE FIRST AND SECOND METACARPALS — NOTE.—These injections were made to determine the relation of these spaces to the thenar space and the remainder of the subcutaneous tissue on the dorsum.

in which pus has pointed here, probably through an imperfect palmar fascia. This was the only experimental injection in which a mass appeared in the palm. (See experimental injection drawing, Fig 31)

Experiment 34—Result same as 33 except no subdermal palmar extension

Experiment 35—Mass filled thenar space, no extensions except along index lumbrical canal.

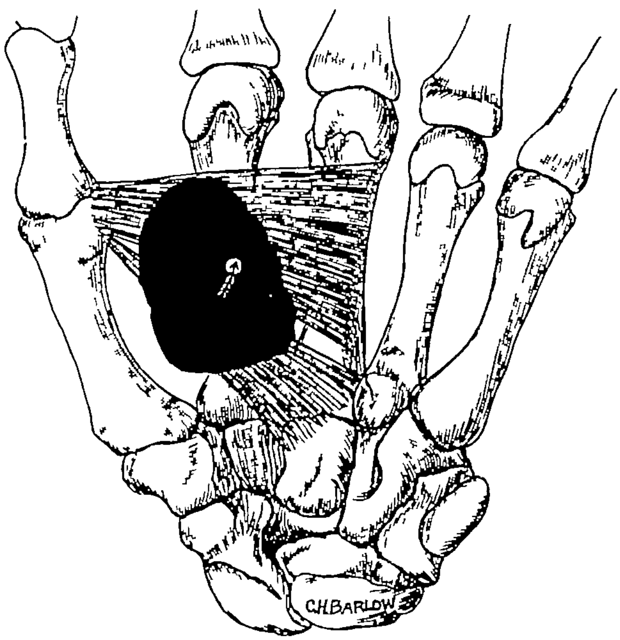


FIG 32—Schematic drawing made from a dissection of a hand in which the injection was made through the palmar fascia into the thenar space

INJECTION THROUGH PALMAR FASCIA IN ATTEMPT TO REACH THENAR SPACE—To reach this space the cannula should be inserted on a transverse line at the middle of the palm, 1 cm to the thenar side of the adduction flexion crease of the thumb

Experiment 36—Left hand Cannula inserted into the middle of the thenar space, moderate force used in injection Mass was found to have filled the space completely, but to have not followed along the index lumbrical muscle to the finger, nor had it gone to the dorsum under

The Dorsal Subaponeurotic Space.

Injection Under Tendons of Dorsum —The importance of this series is seen when we remember that it is in this space that pus would lie if it originated from an osteomyelitis of a metacarpal bone The results obtained were uniform.

Experiment 43 —Right hand Cannula tip inserted under tendons between middle and ring fingers at distal third of dorsum. Considerable force was used in the

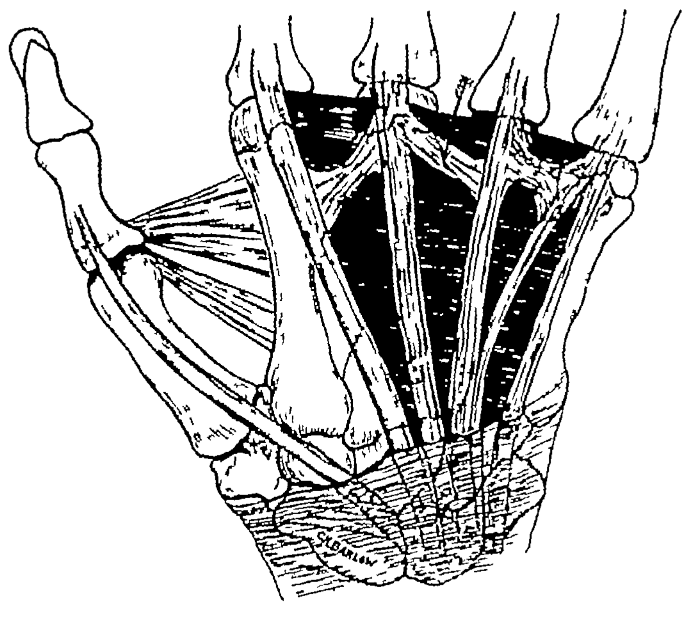


Fig 34 —Schematic drawing made from a dissection of a hand in which the injection was made underneath the aponeurosis of the dorsum, the subaponeurotic space being filled

injection. The mass was confined to the space under the tendons, *i e.*, was covered by the tendons and the aponeurosis between them. It passed up to the wrist, down to within ½ inch of the fingers, and laterally to index metacarpal and little finger metacarpal; thus having the shape of a truncated cone flattened on one side The mass appeared to be ready to break out upon the ulnar side, but none had done so. (See experimental injection drawing, Fig 34)

Experiment 39 —Injection right hand. Moderate force; insertion into subcutaneous tissue on dorsum, thenar region Mass was found to be subcutaneous, and while there was evidently a tendency to limitation at the index metacarpal, yet it is doubtful if it was due to the attachment of fascia to the bone, being more likely to be the natural tendency to limitation found in the meshes of any loose tissue Moreover, in spite of the partial limitation at this point, it had spread into the subcutaneous tissue superficial to the finger tendons, going from the wrist proximally to the metacarpo-phalangeal articulation distally and over to the level of the fourth metacarpal bone. It did not go through to the palm by any channel.

Experiment 40 —Injection of left hand same as above. Mass upon dissection found to occupy dorsal thenar subcutaneous tissue over to the index metacarpal, beyond which it did not extend It did not pass to the palmar surface nor into the thenar space

INJECTION OF THE SUBCUTANEOUS TISSUE OF THE DORSUM BETWEEN SECOND AND THIRD METACARPAL BONES —*Experiment* 41 —Right hand Cannula inserted into subcutaneous tissue of dorsum of hand and the mass injected with considerable force The tip of the needle was superficial to the tendons, but deeper than the superficial layers immediately beneath the skin Upon dissection, mass was found to occupy a considerable space extending from the wrist above to the metacarpo-phalangeal articulation below, and from the metacarpal bone of the index finger to the metacarpal bone of the little finger, proximally and distally, at the wrist and fingers respectively, the tissue seemed to be bound more firmly to the underlying tissue than laterally

Experiment 42 —Left hand Technique and results same as Experiment 41. A study of these two show several layers of fascia between the skin and tendons, with no single space more distinct than another

great force was used, the masses in the lumbrical canals passed out into the loose tissue of the web; also the mass

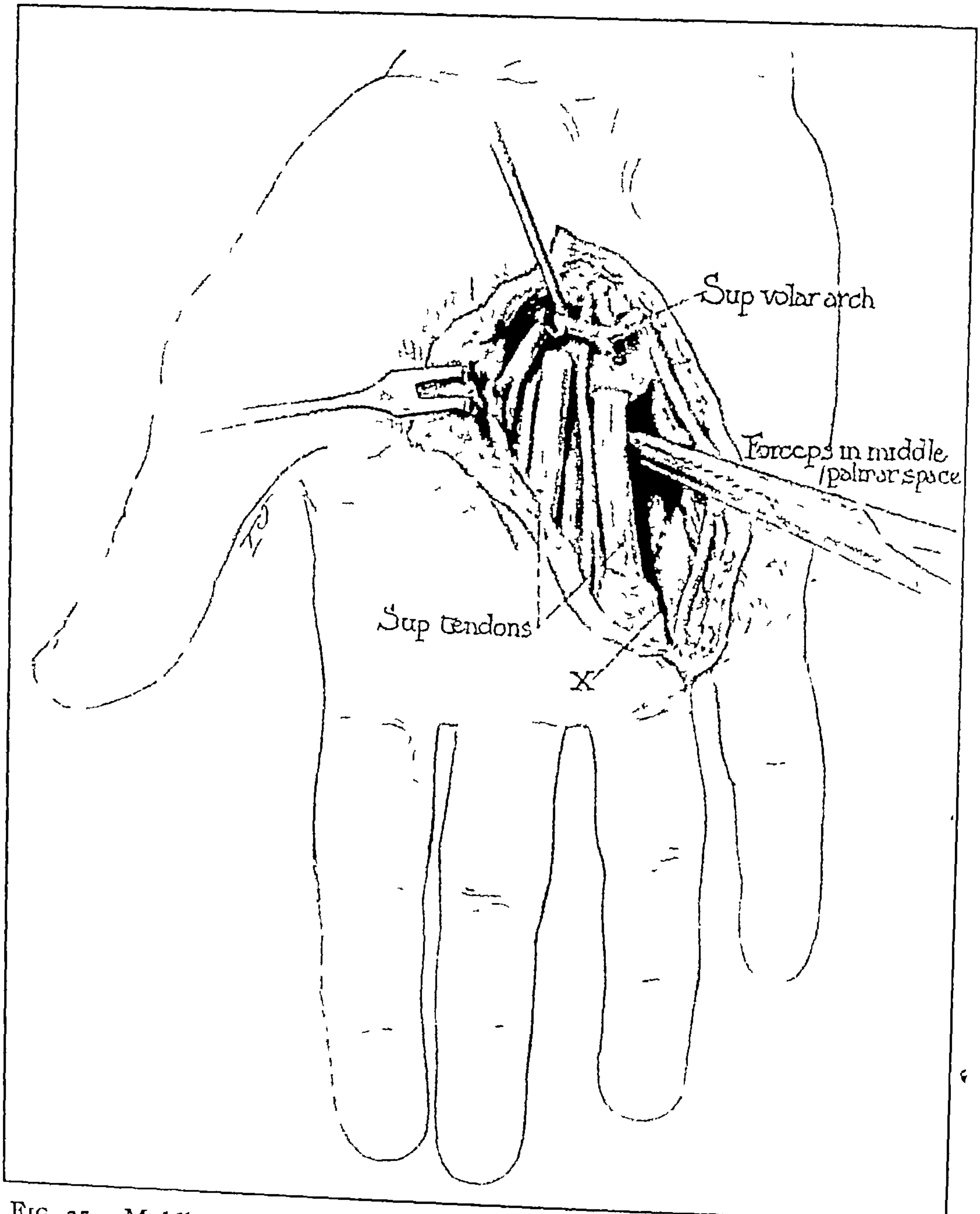


FIG 35 —Middle palmar space (X) Prolongation of middle palmar space into lumbrical muscle space

filling the space proper passed infrequently upward under the tendons into the forearm, where it spread beneath the deep muscles nearly up to the elbow before it came

Experiment 44 —Left hand. Technique and results same as Experiment 43

Experiment 45 —Right hand Cannula inserted between tendons of ring and little fingers, at the middle of the dorsum of the hand, entire subaponeurotic space filled, no tendency to rupture between tendons, but evidence of beginning extension at two sides over index metacarpal and little finger.

The Hypothenar Space.

Many experiments were made to determine the limitations of this space The injections spread from the site of injection only after considerable manipulation, and then the mass was limited to the hypothenar area, near the point of insertion The details of the other injections are omitted, since they only corroborate the findings already noted

Résumé of Preceding Experiments as to Boundaries and Diverticula of the Major Fascial Spaces and Extension From Them

That we may have a clear understanding of the results obtained by experimental injection, let us summarize them The mass in the *middle palmar space*, in practically every case, filled the space we have outlined (Figs 26, 35, and 36). In no case did it extend into the hypothenar area or to the radial side of the middle metacarpal bone, except in the case noted, where a band was tied about the wrist in which the mass then ruptured into the thenar space In every case there was some extension along the lumbrical muscles, almost always going down between the bases of the middle and ring fingers, and sometimes between the little and ring fingers, and, more uncommonly, the middle and index fingers Unless great force was used, this was the limit of the extension When

The *thenar space* was found to be a large space, but lying very deep (Figs. 31 and 32). It was not continuous with the subcutaneous tissue of the dorsum, and

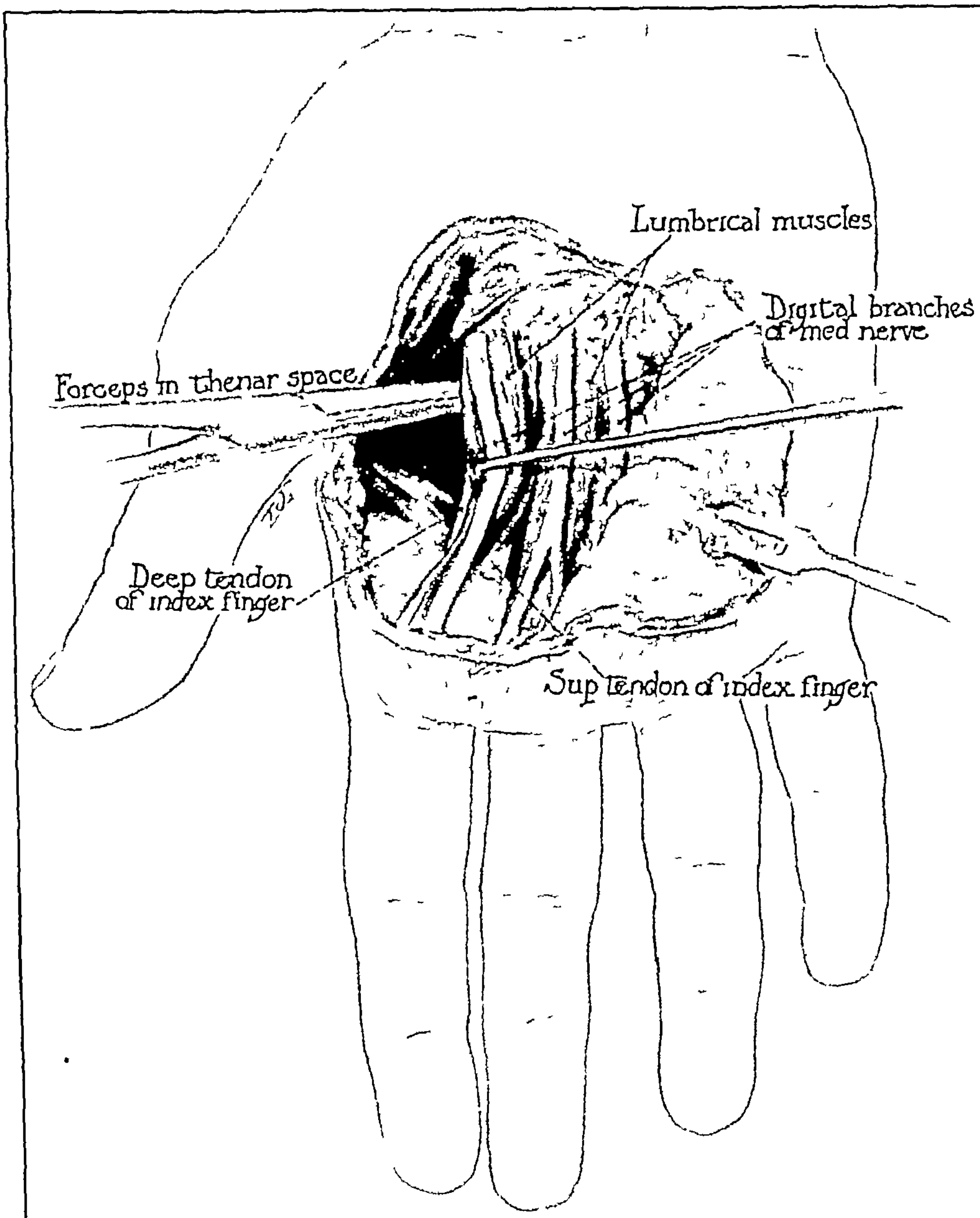


FIG 37 —Showing thenar space

the mass was limited at the free palmar edge of the radial side of the palm The mass did pass, however, when force was used, into the perimuscular spaces on the dorsum, passing proximally and less frequently dis-

to the surface at the lower part of the forearm on the ulnar side It should be emphasized, however, that in case of an infection in the middle palmar space this

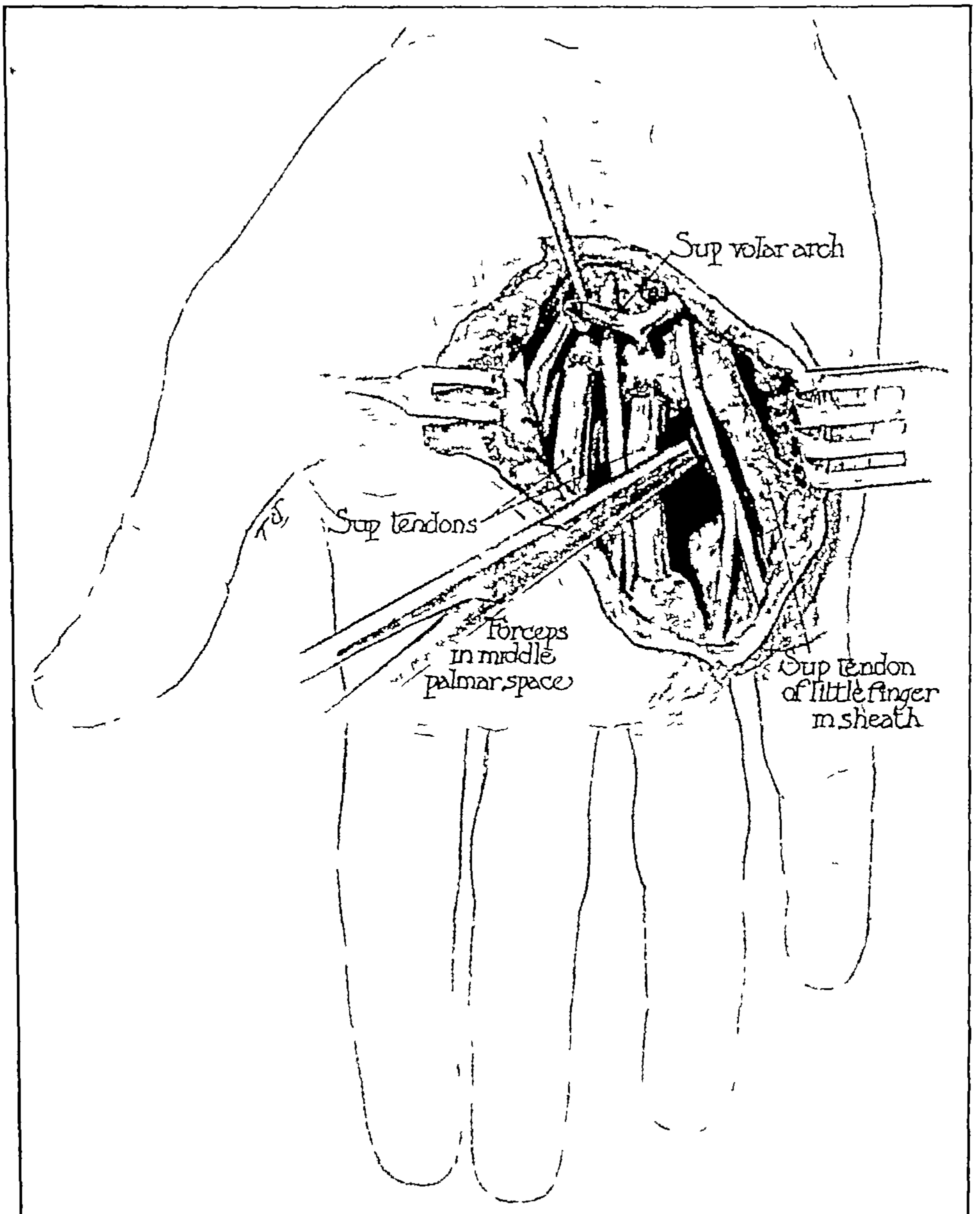


FIG 36 —Showing extension of middle palmar space under synovial sheath of little finger tendons

extension would be exceptional since inflammatory swelling at the carpal canal would obliterate the small canal going up into the forearm In no case did the mass go between the bones to the back of the hand.

Deep injections of the palm went into the thenar or middle palmar spaces, and since these spaces do not overlap, except at the wrist, only one space is affected by a given punctured wound It must be remembered, however, that the lymphatic channels from the center of the palm pass deeply into the tissue and come to lie immediately adjacent to the adductor pollicis (transversus), so that theoretically a lymphatic abscess from a punctured wound might lie in the thenar area, although the puncture might be at the ulnar side over the middle palmar space although I have never seen such an extension.

When the masses spread up into the forearm they appeared under the flexor digitorum profundus in a space I have designated as the *major forearm space* This subject is considered as a whole in the next chapter, devoted to a study of the various spaces in the forearm.

tally to the adductor pollicis (transversus), lying between this muscle and the first dorsal interosseus. It also spread down along the lumbrical muscle of the index finger, making a diverticulum from ¼ to ½ inch long In no case did it spread up into the forearm, even though anatomical dissection demonstrated that this would be possible, although improbable, and if it did it would occupy the same site as that described for masses coming from the middle palmar space In no case did the mass lie to the ulnar side of the middle metacarpal bone, unless great force was used in the injection, then it passed through the upper part of the septum and filled the middle palmar space in one-third of the cases.

Injections into the *hypothenar area* showed the spaces to be localized and perimuscular for the most part, not communicating with any large space, and hence of no particular surgical importance

Injections of the *subaponeurotic space* demonstrated that the mass would not rupture through the aponeurosis unless anatomical exceptions were present It would spread up to the level of the wrist, down as far as the metacarpo-phalangeal joint, and laterally to the edge of the index or little finger tendon on the radial and ulnar sides respectively If greater force were used, it tended to spread under the subcutaneous tissues, particularly on the ulnar side and at the knuckles

Injections of the *dorsal subcutaneous space* showed no particular pockets, but did show a tendency to localization at any site injected because of the obliquity of fibrous bands crossing from space to space If the injections were given with great force, the mass spread equally in every direction, except that there seemed to be some particular factor at work limiting in a certain measure the spread of the mass over the index metacarpal from the dorsum of the hand to the thenar dorsal region, and *vice versa*.

part of the sac of each lies upon the dorsal surface of the tendons, *i e.*, between the tendons of the flexor digitorum profundus and the pronator quadratus (Fig. 152) Again, one should note that the bloodvessels and nerves are surrounded by fascial spaces and when pus once reaches them it can spread easily along these as channels.

Before beginning this study one should be familiar with the general anatomy of the forearm, particularly the relations of the flexor carpi ulnaris, of the flexor digitorum profundus as a group, of the flexor digitorum sublimis as a group, of the course of the median and ulnar nerves, and of the ulnar and radial artery, especially the former, also the relation of the pronator quadratus and the ulna and radius with the interosseous membrane in one group to the flexor digitorum profundus With these general facts in mind, let us now take up the study of the cross-sections

SERIAL CROSS-SECTIONS OF THE FOREARM

The cadaver arms were hardened in Kaiserling No 1 After being sectioned the pieces were preserved in Kaiserling No 2 Sections were made at the following distances from the radial styloid 3 cm , 7 cm , 9 cm , and 12 cm The proximal surfaces of these sections were teased out with a needle and forceps The large spaces found were packed with cotton or held open with small props and photographs taken to show their relation to the other structures of the forearm One particularly large free space was found in the lower part of the forearm lying between the flexor profundus group and the pronator quadratus It is upon this that we will center our attention

Section 1 (Fig 38) —*Three centimeters above radial styloid* The space is rather small here, opening out from the narrow canal that connects it with the middle

CHAPTER V

ANATOMY OF THE FOREARM IN RELATION TO INFECTIONS—THE MAJOR FOREARM SPACE

EARLY in my clinical work it was found that there was little knowledge as to the sites of predilection for pus in the forearm when it extended from the hand. Experience showed that incisions made at the sites suggested by various authors were followed by a tedious convalescence owing to the necessity of maintaining satisfactory drainage through the muscular bodies. A study of the forearm after the same methods already pursued in the hand was begun, namely, the dissection of serial sections and injection of plaster of Paris from various sites. As a result of this, I changed entirely the sites of my incisions, making 1 or 2 or at most 3, and had the great satisfaction of seeing patients, who under the old methods of incision required weeks of constant attention and multiple incisions, heal in a week to ten days. Parona, as quoted by Mauclaire, has suggested the advisability of one of these incision—that upon the ulnar side above the wrist.

The anatomical and experimental data upon which these incisions were based are detailed in brief in this chapter.

ANATOMY IN GENERAL

In general one should remember that the synovial sheaths, *i. e.*, the ulnar and radial bursæ, pass under the transverse carpal ligament and extend into the forearm for a distance varying from 1 to 2 inches. The greater

flexor surface of the ulna and radius It is at this site that drainage is instituted.

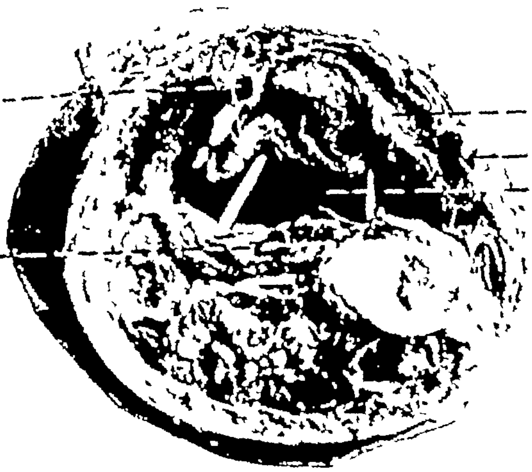


FIG 39 —Section 7 cm above radial styloid *UA*, ulnar artery, *UN*, ulnar nerve, *MN*, median nerve, *RA*, radial artery, *S*, major forearm space, *PQ*, pronator quadratus

Section 3 (Fig 41)—*Nine centimeters above radial styloid.* In this section the pronator quadratus has

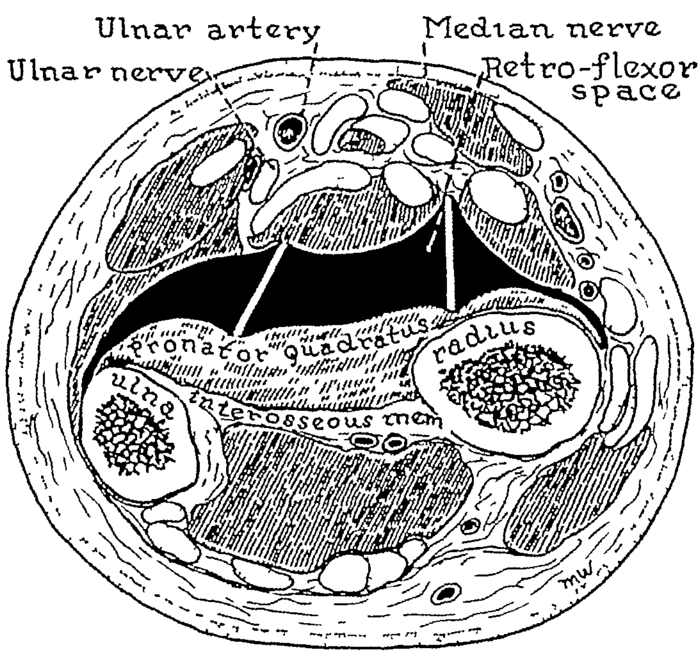


FIG 40 —Drawing from teased cross-section (Fig 39) The retroflexor space (shown in black) is the major forearm space

almost entirely disappeared The space is now bounded dorsally by the interosseous membrane with the artery

palmar space in the hand It extends well across the forearm, but is slightly larger upon the radial side The vessels and nerves are separated from the space by well-defined layers of muscular and connective tissue. Upon the superficial surface it has the tendons of the flexor digitorum profundus, covered by their synovial sheath, and the flexor pollicis longus, covered by its synovial sheath. On the radial and ulnar sides there is nothing but the subcutaneous tissue and the fascia attaching the flexor body of muscles to the bones On its deep surface is found the pronator quadratus.

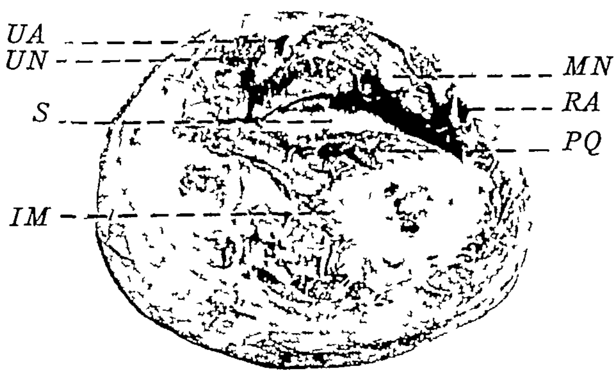


FIG 38 —Section 3 cm above radial styloid *UA*, ulnar artery, *UN*, ulnar nerve, *MN*, median nerve, *RA*, radial artery, *S*, major forearm space, *IM*, interosseous membrane, *PQ*, pronator quadratus

It is seen that if pus should rupture from the synovial sheaths or pass upward from the middle palmar space, it would enter this free area It is manifest that a large accumulation could take place here Its most superficial sites would be upon the sides

Section 2 (Figs 39 and 40) —*Seven centimeters above radial styloid* The relation of the structures has not changed materially The body of the pronator quadratus is somewhat smaller The space is still large and extends well to the ulnar side

By comparing this with the other sections it will be seen how little tissue lies on the sides at the level of the

flexor surface of the ulna and radius. It is at this site that drainage is instituted.

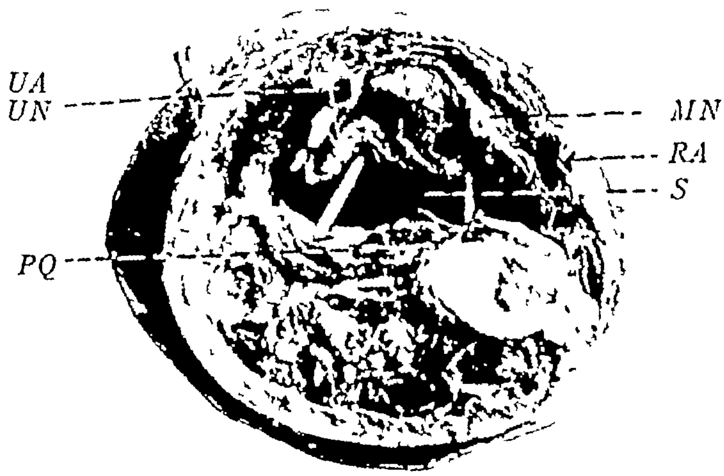


FIG 39 —Section 7 cm above radial styloid *UA*, ulnar artery, *UN*, ulnar nerve, *MN*, median nerve, *RA*, radial artery, *S*, major forearm space, *PQ*, pronator quadratus

Section 3 (Fig 41) —*Nine centimeters above radial styloid.* In this section the pronator quadratus has

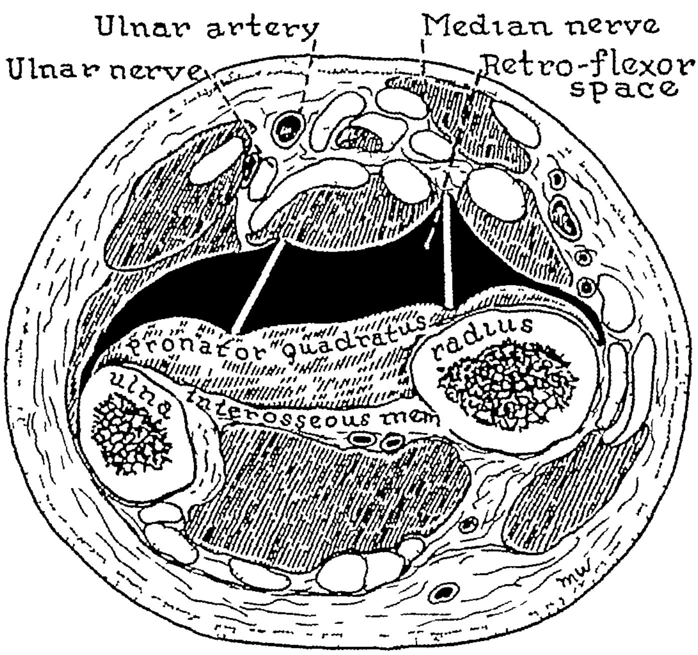


FIG 40 —Drawing from teased cross-section (Fig 39) The retroflexor space (shown in black) is the major forearm space

almost entirely disappeared. The space is now bounded dorsally by the interosseous membrane with the artery

exposed The other structures remain in the same relation to the space The radial and ulnar arteries and the median and ulnar nerves are still well separated from the



FIG 41 —Section 9 cm above radial styloid Pronator quadratus has almost disappeared Notice that the vessels and nerves, with the exception of the interosseous (*IA*), are well separated from the major forearm space (*S*).

space Attention will be drawn to this fact later in discussing treatment

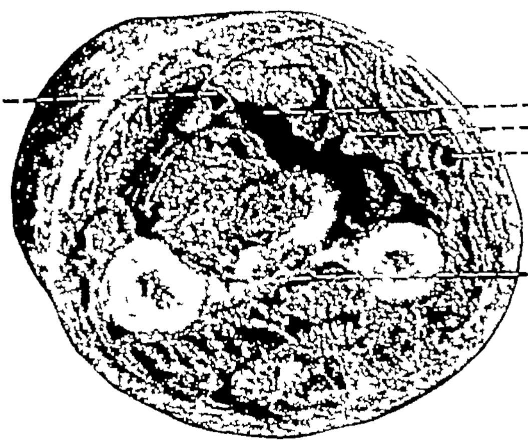


FIG 42 —Section 12 cm above radial styloid Note the relation of the space to the median nerve and the ulnar artery *IA*, interosseous artery, *S*, major forearm space

Section 4 (Fig 42) —*Twelve centimeters above radial styloid* In this section the space is leaving the interosseous membrane and passing toward the flexor surface on the radial side of the deep flexors. It extends to the

median nerve and over to the ulnar artery and nerve along the ulnar side The radial artery is well separated from the space

This relation of the space to the bloodvessels and nerves explains why the injection masses go up the forearm and then pass in a retrograde manner toward the hand along these structures. It also explains those cases in which the injection mass passes proximally along the median nerve to the elbow It helps to explain the trophic sequelæ and cases of ulcerative hemorrhage that have been reported. In the upper part of the forearm the space follows the nerves and bloodvessels and becomes indefinite It is seen that the ulnar nerve and artery along which the secondary mass extends lie immediately under the junction of the flexor carpi ulnaris with the flexor profundus digitorum at about the middle of the forearm. This indicates then a second site for incision in neglected cases (Figs. 42 and 153)

EXPERIMENTAL INJECTIONS OF THE FASCIAL SPACES OF THE FOREARM

To verify the findings here, experimental injections were made with plaster of Paris from various sites that might be the origin of spreading abscesses These will show the intimate relation which exists between the fascial spaces of the hand and the forearm and those about the bloodvessels

It should be remembered that we are only selecting illustrative experiments which bear upon the subject in hand, and that those here presented do not by any means represent a complete report of the results obtained from injections at these various sites

Injection of the Radial Bursa

Out of the eight injections made into the radial bursa under high pressure to produce rupture and extravasation

of the mass reported in the previous chapter, six showed extension from a rupture at the proximal end into the forearm The following may be taken as an example of the condition found upon dissection of the arm

Experiment 46—Injection under great pressure of synovial sheath of flexor pollicis longus by plaster of Paris.

Upon dissection the mass was found to have filled the synovial sheath completely and ruptured from the proximal end into the tissue of the forearm No extension had taken place into the hand either by rupture of the sheath in continuity or by retrograde movement from the forearm under the transverse carpal ligament, although the mass had extended down to the transverse carpal ligament and lay under the superior border The attachment of the flexor pollicis longus to the bone was partially destroyed, owing possibly to the friability of the muscle in this particular cadaver, but the mass showed a tendency to follow this muscle and a predilection for the radial side of the forearm A portion of the mass laid between the flexor pollicis longus and the flexor digitorum sublimis The larger part, however, extended underneath the flexor digitorum profundus to fill a space bounded on the ulnar side by the flexor carpi ulnaris, on the radial side by the flexor pollicis longus, dorsally by the bones with the interosseous membrane and pronator quadratus This extended up to within 3 inches of the elbow-joint and distally to the wrist-joint A great amount of material was present The area filled was practically that described in the cross-sections, except that the mass did not extend between the flexor carpi ulnaris and the flexor profundus

Injection of the Ulnar Bursa

Injection of the ulnar bursa resulted frequently in rupture at the proximal end and the mass filled the major forearm space described above, between the flexor digi-

torum profundus and the pronator quadratus It showed a great predilection for the ulnar side, and had a tendency to follow along the course of the ulnar artery The extension along this vessel explains the presence of the ulceration and secondary hemorrhage from the ulnar artery which occurs at times

Experiment 47—Injection of the ulnar bursa, rupture from proximal end, filling the major forearm space (Fig. 22)

The ulnar bursa was injected with great force. Rupture occurred at the proximal end in the forearm, the mass was found to fill space described above, being dorsal to the flexor profundus tendons and muscles and lying upon the pronator quadratus and interosseous membrane It showed a primary predilection for the ulnar side, but higher up the arm passed to the radial side of the profundus tendons along the intermuscular space and returned distalward along both the ulnar and radial vessels There was also an extension along the median nerve, this tongue of plaster following the nerve to 2 inches proximal to the elbow-joint

Injection From the Mid-palmar Space

What is the result when the mass extends from the mid-palmar space of the hand?

Experiment 48—In this case both the thenar and middle palmar spaces were injected with force from the index and ring fingers respectively The thenar mass remained in its usual compartment, while the middle palmar mass extended along the lumbrical muscles and also passed up under the group of flexor tendons into the forearm to fill the major forearm space

Experiment 49—Injection with great force through synovial sheath of the ring finger so that the mass filled the mid-palmar space and extended under the transverse carpal ligament into forearm.

The mass was injected with considerable force. The middle palmar space as described was filled Thenar and hypothenar areas were free The mass extended along the little and ring finger lumbricals for ¾ inch, none along other fingers, none through between bones to back It passed under the tendons up into forearm, where a large mass was found lying under the deep muscles upon the pronator quadratus and interosseous septum It extended into the intermuscular fascial spaces up to the pronator teres and came to the surface late upon the radial side at about 2 inches above wrist, but the mass was most marked upon the ulnar side from above downward between the flexor carpi ulnaris and the deep tendons and muscles, so that this upper mass was most easily reached by separating the flexor carpi ulnaris along its volar edge from the adjacent muscular body. This also exposed the ulnar artery and nerve which were surrounded by the mass

These two experiments represent the anatomical possibility of the spread of pus from the middle palmar space into the forearm, clinically, however, it practically never occurs Only one such case having come to my knowledge.

RÉSUMÉ—THE MAJOR FOREARM SPACE

By these experiments we have demonstrated that in neglected cases, no matter whether the pus extends up from the ulnar bursa, radial bursa, or the mid-palmar space, the same area of the forearm is involved They have also defined the outlines of this space which I have named the *major forearm space* (Fig 43) Its floor is the pronator quadratus and the interosseous membrane and its roof the flexor digitorum profundus At the sides it is separated from the skin by fascia extending from the muscles to bones, so that its most superficial parts lie on either side just volar to the flexor surface of the ulna and radius This space will hold a half pint or

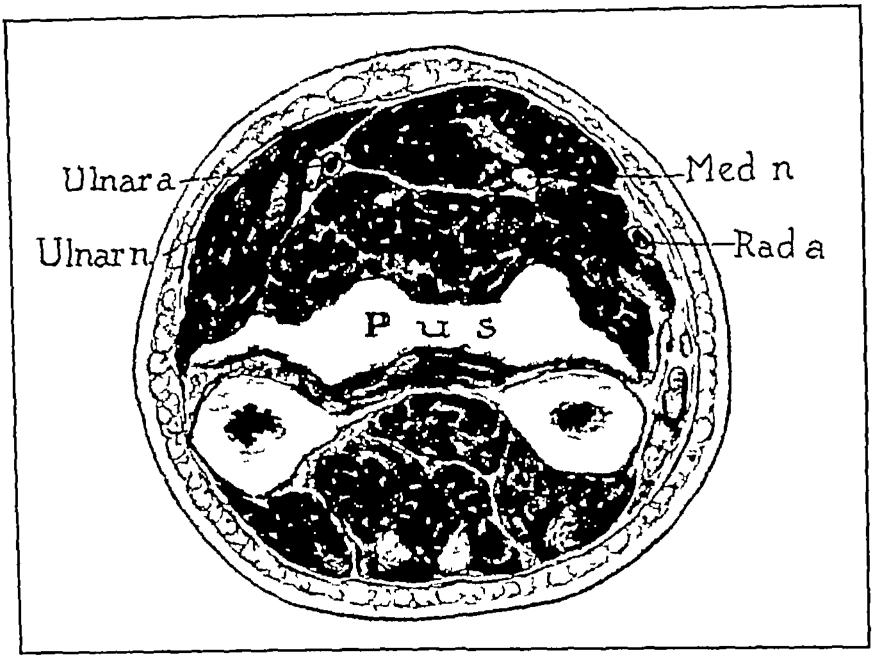


FIG 43 —Cross-section 7 cm above radial styloid, showing site of pus in the major forearm space

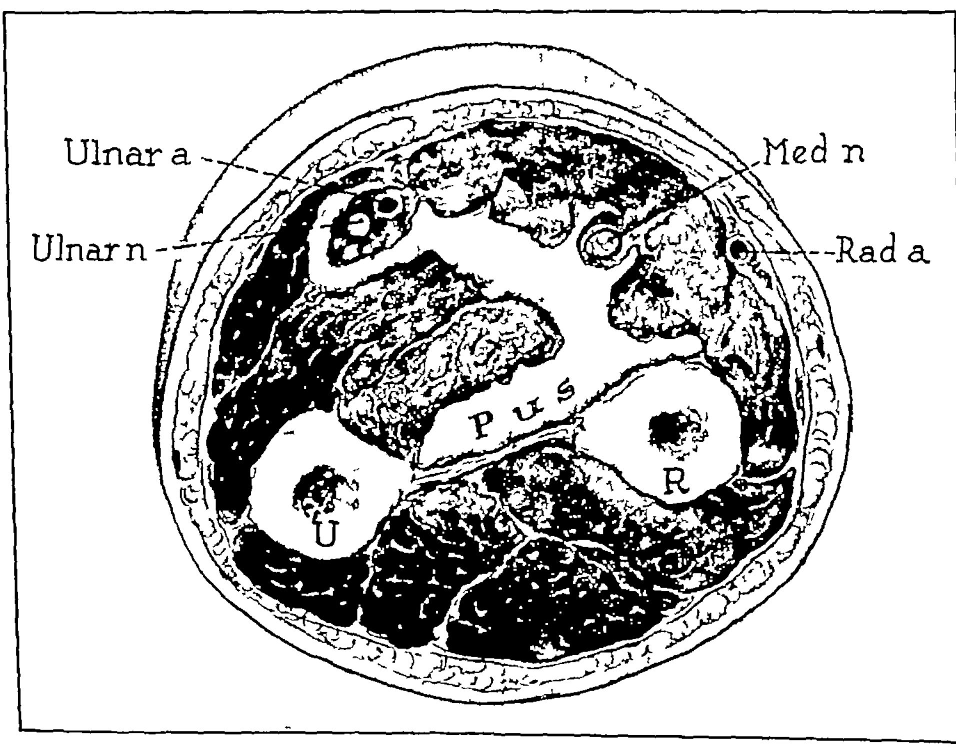


FIG 44 —Cross-section of forearm just distal to the middle, showing site of pus and its relation to the ulnar artery and nerve and the median nerve

more of pus About 3 inches up on the forearm the pus begins to invade the intermuscular septa to the radial side of the flexor digitorum profundus, passing first to the area about the median nerve, and later to the area about the ulnar artery and nerve. Here it lies between the flexor carpi ulnaris and the flexor profundus (Fig 44) This is about 4 to 5 inches up on the forearm The pus may pass toward the elbow along the vessels and nerves, particularly the median nerve, or, more commonly, it may extend distally along the ulnar artery under the flexor carpi ulnaris, and appear subcutaneously about 3 inches up on the ulnar side It may extend downward along the radial artery, but this is certainly an uncommon termination.

The only other distinctly separated space is that comprising the subcutaneous tissue

(For the surgical application of these facts see Part III)

CHAPTER VI

ANATOMY OF THE LYMPHATICS

IN order to understand the pathogeny of lymphatic abscesses, an accurate knowledge of the position and course of the lymphatic vessels is absolutely essential. The masterful work of Mascagni and later work by Sappey have been fully reviewed and verified by Poirier, with the assistance of his pupil Cuneo I myself began a study of the anatomy of the lymphatics, using Gerota's method of injection, but since nothing was being added to our knowledge the studies were abandoned and the accompanying description of their anatomy taken largely from the admirable contributions of Sappey, Poirier and Cuneo We so often see the superficial lymphatics in the course of surgical practice that we are inclined to forget that there are deeper lymphatics which follow the deeper vessels Sappey believed that these two systems were absolutely independent. Poirier, however, maintains that communication is fairly common, especially in the articular regions. It is important to remember that the principal lymphatic vessels and glands lie superficial to the large veins and seldom deep. The clinical significance of this is apparent to the surgeon Another general point of importance is that the texture of the surrounding connective tissue influences their shape and number. If the connective tissue is lax, their tendency is to run together and become sinuous and sacciform (Fig. 45). Consequently the infection is likely to localize in the looser connective-tissue areas This probability is accentuated by the fact that glands, either microscopic or macroscopic, show a predilection for these areas The fact that

sacciform dilatations and microscopic glands do occur explains the production of abscesses in the course of an

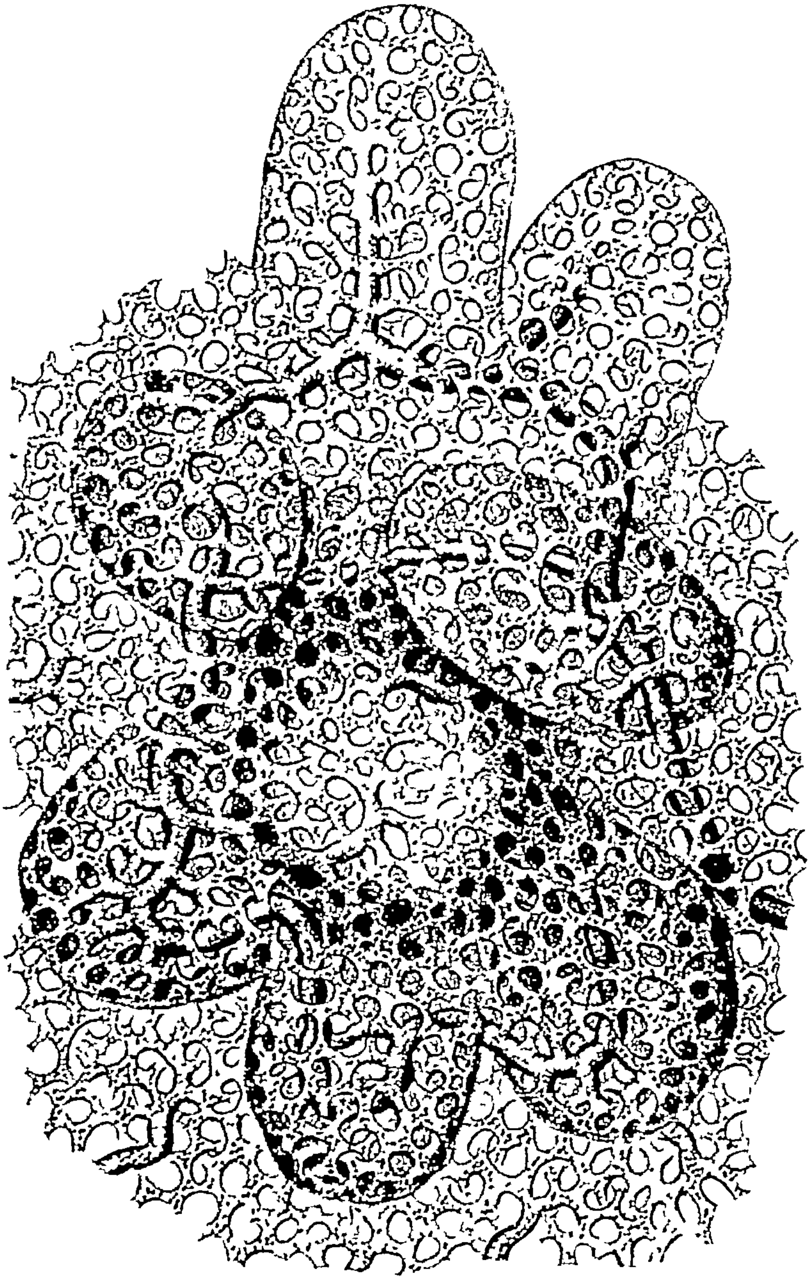


FIG 45 —Drawing showing lymphatics grouped about a hair follicle on the dorsum Character of lymphatic tissue commonly seen in loose connective-tissue spaces (After Sappey)

apparently uninterrupted lymphatic More commonly, however, we see simple inflammatory swellings without

pus formation at these sites. Moreover, the variability both in the number and the position of these glands renders absolute statements as to their position impossible. Not alone are microscopic glands present in the course of the vessels, Gulland has demonstrated them in the axilla, and Stiles has seen axillary glands appear during lactation and disappear on its cessation However, this may be stated· In a given animal and a given region the quantity of glandular tissue is always practically identical Thus if the glands are small they are numerous and if large they are likely to be scarce. In any case, however, they are generally paravascular.

THE LYMPHATIC VESSELS OF THE HAND AND FOREARM.

These may be divided into two groups. the superficial lymphatics, which arise from the integument and whose collecting trunks run in the subcutaneous cellular tissue, and the deep lymphatics, arising in the deeper tissues and in vessels following the deep bloodvessels

SUPERFICIAL LYMPHATICS

These, being easily demonstrated experimentally and seen so often clinically, are well known

"The superficial lymphatics come from all parts of the cutaneous covering of the limb, but it is in the fingers (Fig 46) and the palm of the hand that the net-work of origin is the richest.

"The collecting trunks of the superficial net-work appear at the roots of the fingers and at the base of the palm of the hand (Fig. 47) They then run upward on the forearm and arm, receiving as they ascend the lymph from other parts of the cutaneous covering. They terminate in the glands of the axilla We will study first their digital and palmar origin, and then their course and termination

"Origins (*A*) In the fingers, the net-work of origin presents its maximum of development on the palmar surface (Fig 48). Here the meshes are so closely set that it is only by a careful examination with a lens that they can be distinguished The dorsal net-work is much less rich than the preceding (Fig. 49) From these two net-works arise a considerable number of collectors, which converge toward the sides of the fingers and unite to form two or three trunks on each of these surfaces (Fig. 46). These trunks at first follow the corresponding collateral artery, but, having arrived at the base of the finger, they

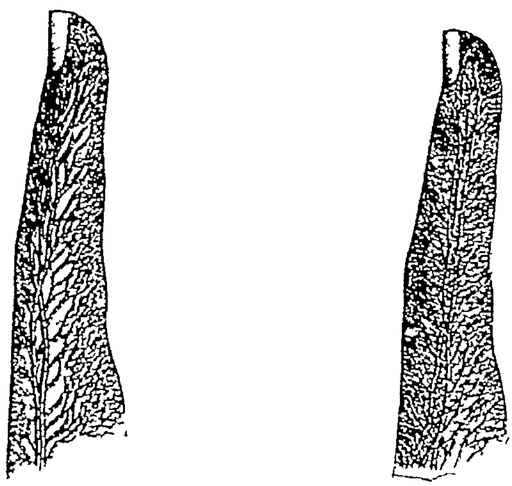


FIG 46 —Net-work of lymphatics on the side of the finger The accompanying drawing represents the trunklets which carry the lymphatic stream to the base of the finger (After Sappey)

incline backward and run toward the interdigital space. They then pass to the posterior surface of the hand, and are directed toward the wrist, where we shall trace them again shortly In their course on the dorsal surface of the hand they effect numerous anastomoses They cross one another frequently, and it is no unusual thing to see a collecting trunk, which has arisen, for example, in the fourth interdigital space, uniting with trunks which run along the external part of the dorsal surface of the hand.

"(*B*) In the palm of the hand the net-work of origin is also extremely rich. From this net-work run numerous

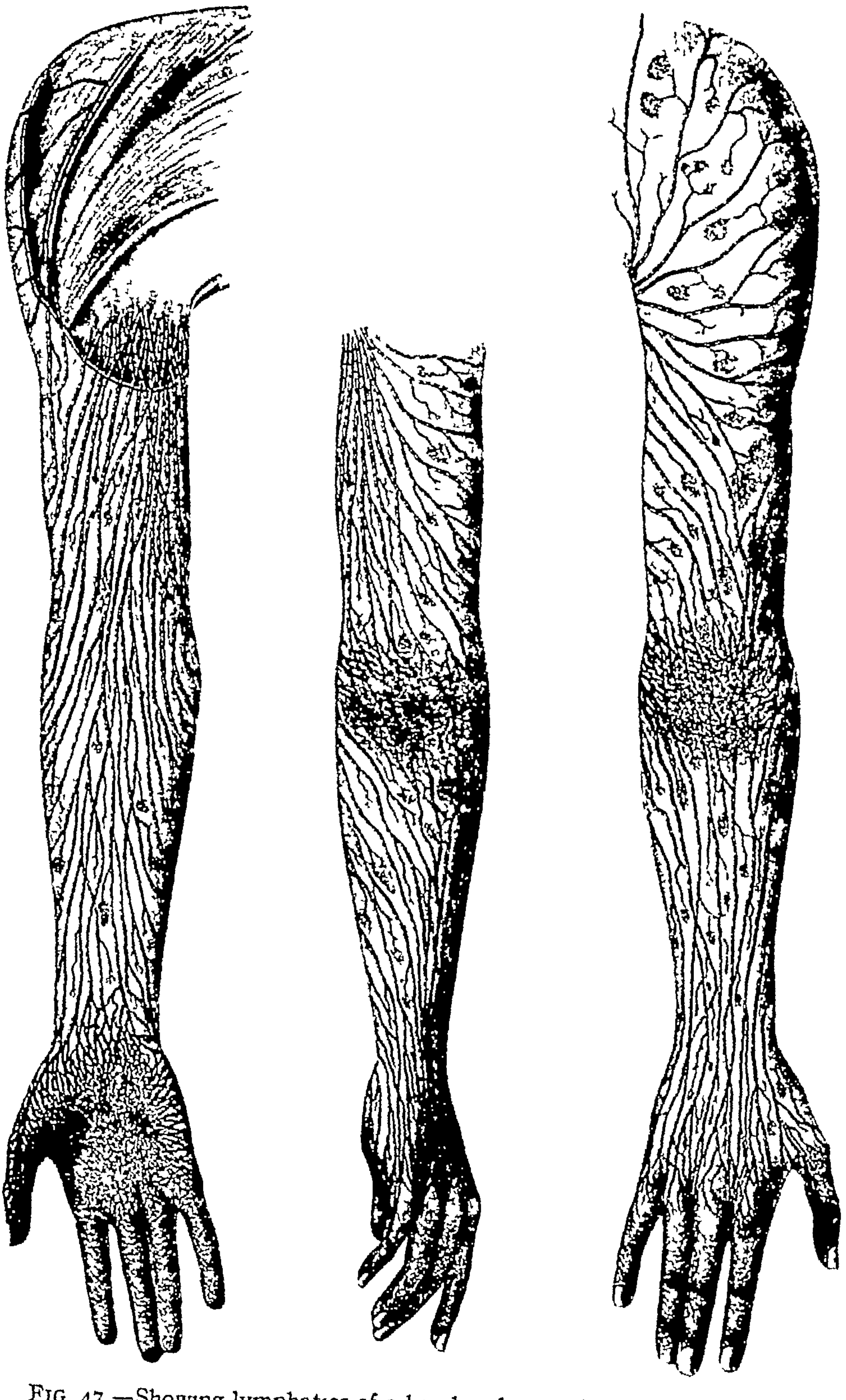


FIG 47 —Showing lymphatics of a hand and arm, the areas of origin and distribution (After Sappey)

trunklets, which we may divide into external, internal, inferior, superior, and central (Fig. 50).

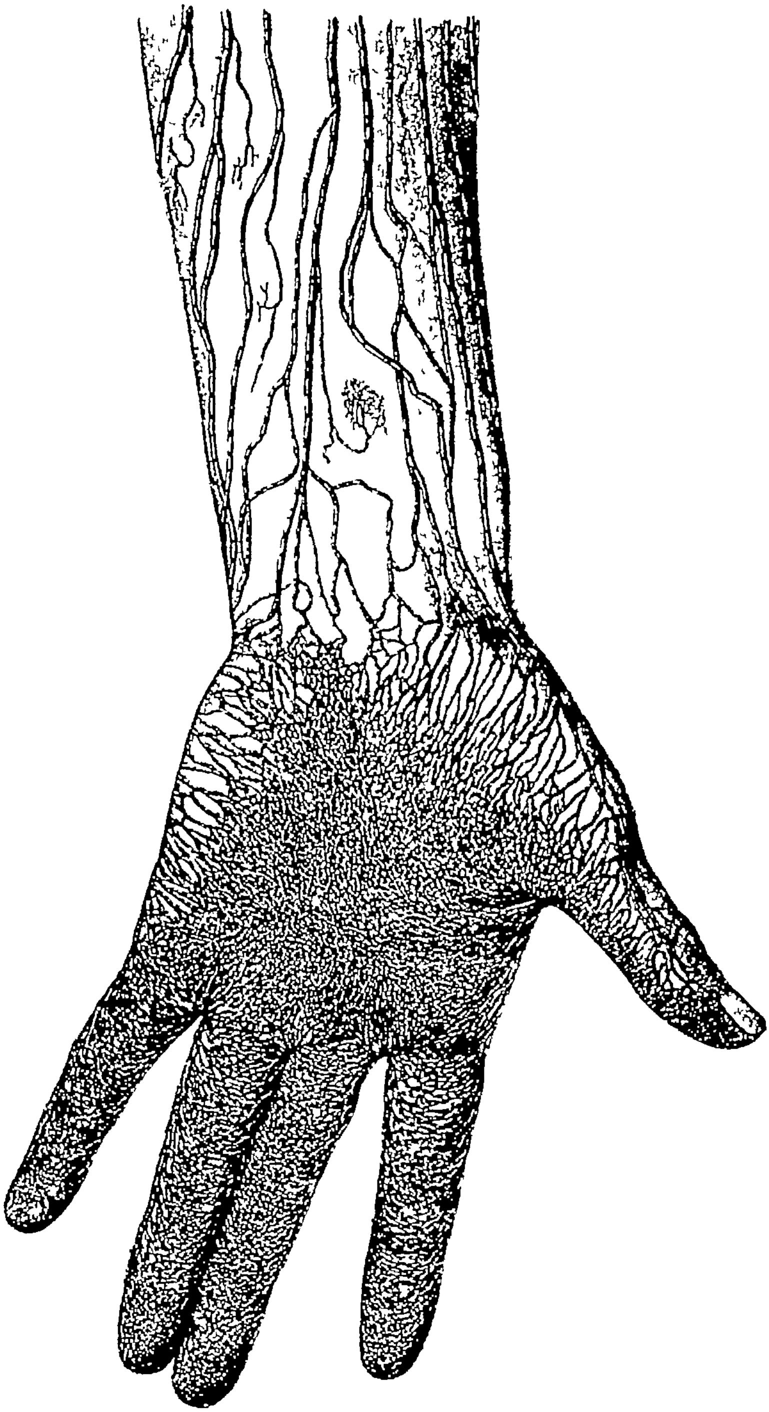


FIG 48 —Showing extensive net-work of lymphatic channels on the palm and fingers, with their extensions to the dorsum and to the forearm through the collecting trunklets (After Sappey)

"The external trunklets, four to six in number, run obliquely upward and outward, and, crossing the surface of the thenar eminence in a slanting direction, terminate

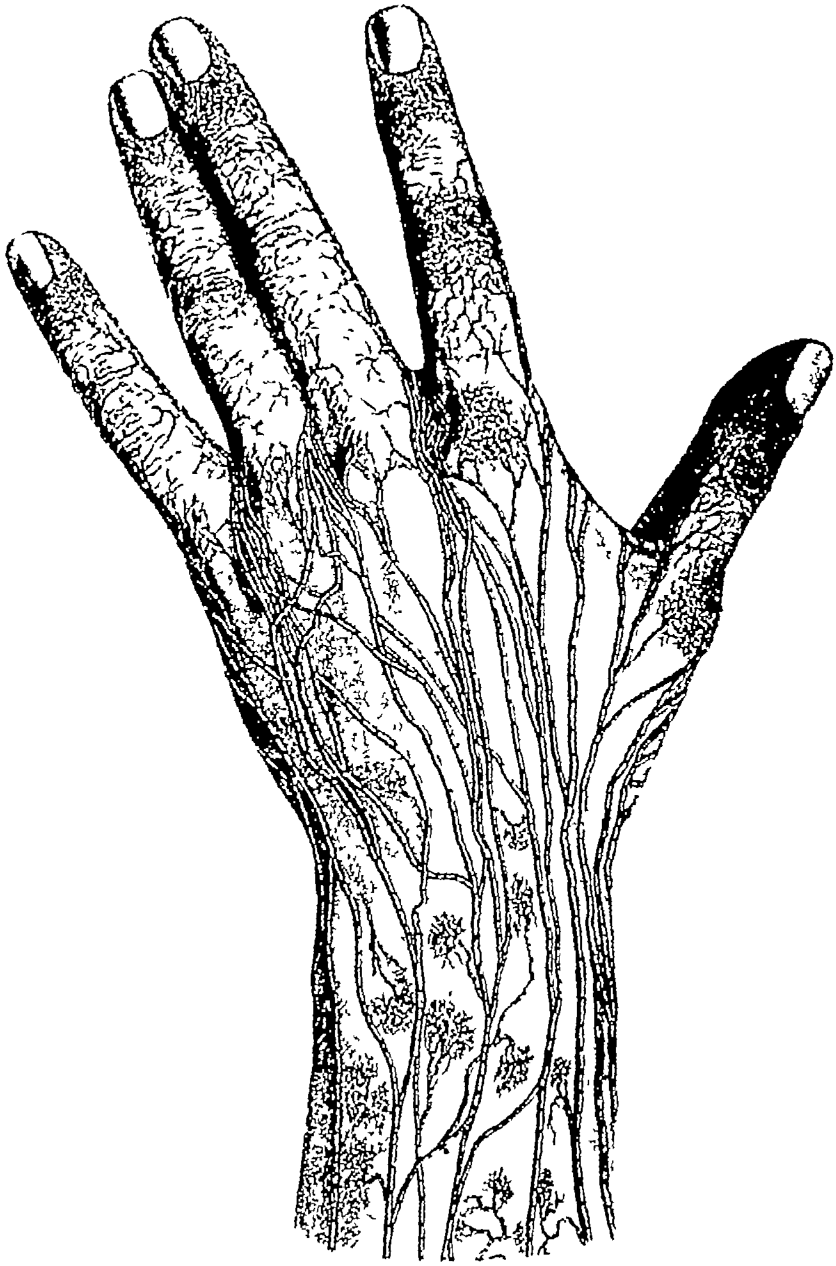


FIG 49 —Showing lymphatics upon the dorsum Note how few there are in comparison with those upon the palmar surface (After Sappey)

in the lymphatics coming from the integuments of the thumb.

"The internal trunklets, more numerous than the

preceding (eight or ten), run almost transversely inward, and, crossing the ulnar border of the hand, reach the dorsal surface and empty themselves into the collecting trunks which arise from the integument of the little finger.

"The inferior trunklets, which vary from twelve to fifteen in number, are directed toward the interdigital spaces, they then reach the dorsal surface of the hand and terminate in the digital collecting trunks

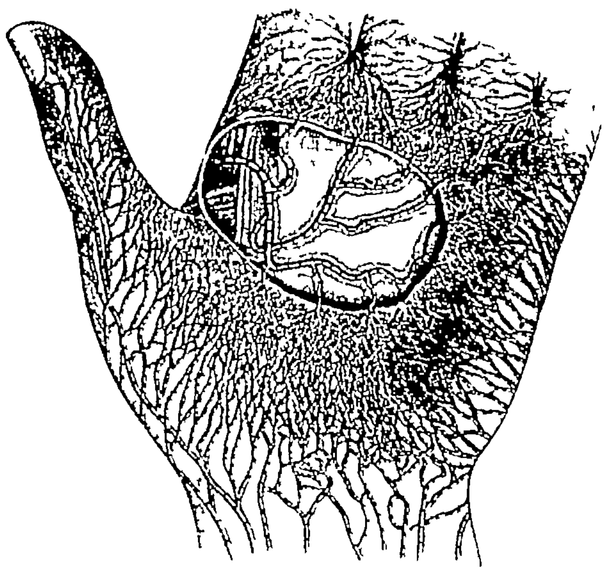


FIG 50 —Lymphatic vessels of the palm, showing their extensions from all the borders to the dorsum and the extension from the central portion into the deep lymphatic along the palmar arch (After Sappey)

"The superior trunklets reach the anterior surface of the wrist, and unite to form three or four trunks, which ascend on the anterior surface of the forearm

"The central trunklets run toward the deep portion They traverse the subcutaneous fatty layer and the superficial palmar fascia, and they usually unite into a single trunk The latter, which has been well described by Sappey, takes the following course It is directed immediately outward, running underneath the fascia in front of the flexor tendons It thus comes to the adductor pollicis transversus, crosses the inferior border of this

muscle, and then crosses the outer border of the first dorsal interosseus, on the posterior surface of which it ascends It there joins collectors coming from the index finger, and in company with the latter reaches the dorsal surface of the wrist

"Course· All these collecting trunks, which arise from the integuments of the fingers and hand, run in the subcutaneous cellular tissue toward the root of the limb They are usually more superficial than the veins whose trunks they cover They diminish in number as they are traced upward In the forearm there are about thirty, but in the middle of the arm not more than fifteen to eighteen (Sappey)

"In the wrist they are divided into two groups, of which one runs on the dorsal, the other on the palmar surface of this part of the limb

"In the forearm they tend to divide themselves into three groups—an external group, which ascends along the radial border of the forearm, an internal group, which follows the ulnar border, a middle group, which is a satellite of the median vein and runs between the two preceding

"A little below the bend of the elbow the two lateral groups come more and more to the anterior surface of the limb and unite with the median group, on the dorsal surface we find nothing but some rather small collecting trunks, which incline obliquely, some outward, others inward, and reach the anterior surface of the arm (Fig 47) At the level of the olecranon these collecting trunks present remarkable sinuosities

"In the arm the different collecting trunks, henceforth united into a single bundle, show a tendency to arrange themselves on the external surface of the arm, parallel to each other

"Termination The majority of these collectors run as far as the neighborhood of the base of the axilla Here,

they perforate the deep fascia and terminate in the humeral chain of axillary glands The collectors from the outermost and innermost parts have quite a different termination, thus, two or three of the most internal end in the supra-epitrochlear gland We have already seen that the efferents of this gland perforate the deep fascia in the middle part of the arm and end in the deep vessels When this gland is absent, we may nevertheless see the internal collectors perforating the fascia at the same point to reach the deep absorbents The most external trunk is also remarkable for the special course it pursues It separates itself from the other collectors in the region of the humeral insertion of the deltoid, then ascends in the deltopectoral groove, where it may traverse one or several glands which we have indicated above This trunk usually passes into a subclavian gland, placed at the spot where the cephalic joins the axillary vein It may also be seen to pass above the clavicle, and to empty itself into the supraclavicular gland This arrangement, though somewhat infrequent (Grossman says 38 out of 100 cases), has been figured by Mascagni This deltopectoral trunk is sometimes double and even triple."

Deep Lymphatics

The deep lymphatics follow the brachial artery and its chief branches There are usually two lymphatic trunks for each artery With Sappey, we will divide these deep lymphatics into radial, ulnar, posterior interosseous, anterior interosseous, and brachial

The radial trunks arise from the subfascial portions of the palm of the hand "One accompanies the deep palmar arch, turns around the head of the first metacarpal bone, and runs on the outer side of the carpus, and reaches the forearm, where it is situated on the external side of the radial artery, the other, whose origin is not so deep, follows, according to the sketch left us

by Mascagni, the course of the superficial volar branch of radial artery, and also joins the forearm, where it is placed on the inner side of the radial. Both then ascend as far as the bend of the elbow, where they anastomose. In their antibrachial course they traverse one or two small glands, the existence of which is not constant." (Sappey)

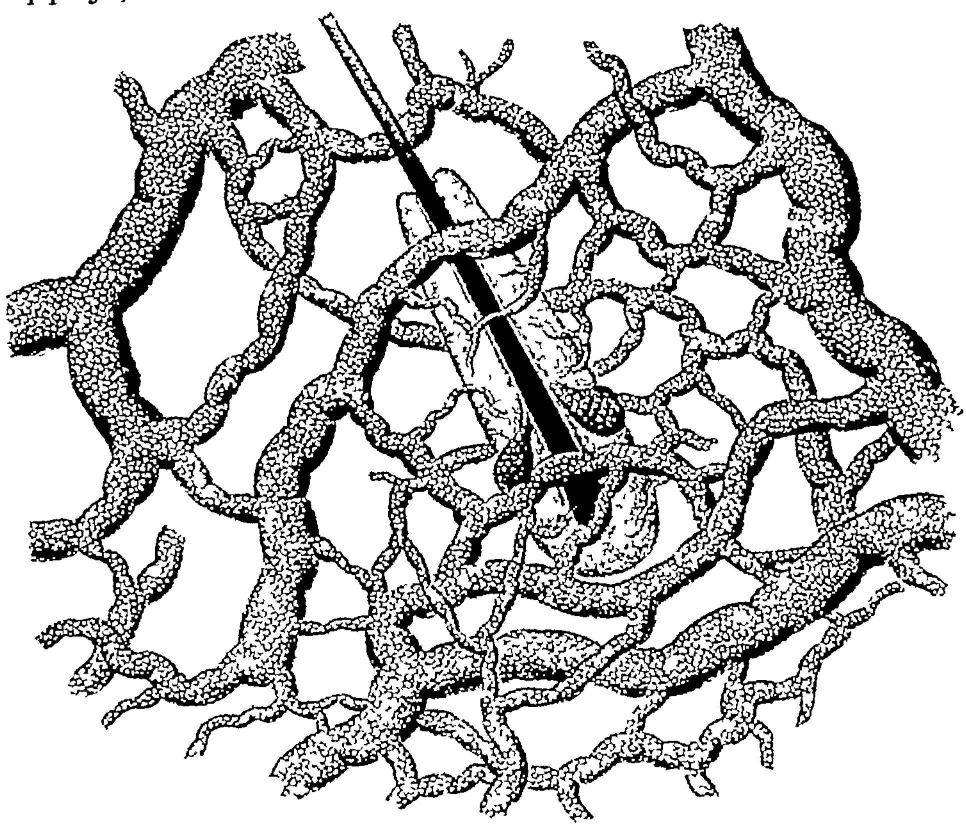


FIG 51 —Showing lymphatics about a hair follicle (After Sappey)

"The ulnar trunks are also two in number. They have a separate origin One, in fact, appears by the side of the superficial palmar, while the other is a satellite of the deep palmar arch. They unite at the wrist, just above which they receive a large affluent which is a satellite of the dorsal branch of the ulnar They then run parallel to the ulnar vessels as far as the bend of the elbow. During their course they sometimes present one or more small glands.

"The posterior interosseous trunks, which arise from

the deep muscles of the forearm, perforate the interosseous membrane and then unite at the bend of the elbow with the preceding vessels

"The anterior interosseous trunks follow the vessels of this name, and, after presenting in their course one or two small glands, also end in the lymphatic meeting-place at the bend of the elbow.

"The humeral trunks comprise all the above-mentioned antibrachial collecting trunks They vary from two to three in number. They run by the side of the humeral vessels, and terminate in the humeral group of the axillary glands As we have already seen, they present in their course some small glands which appear to be nearly always present In the middle part of the arm they collect the efferent vessels from the supra-epitrochlear gland They also receive some small trunks from the muscles of the arm."

RELATIONS OF LYMPHATIC ABSCESSES STUDIED BY EXPERIMENTAL INJECTIONS

In order to determine the position and extensions of abscesses developing along the deep lymphatic, injections of pastes were made along these vessels The information secured added little to our knowledge, therefore the results are presented in an abbreviated form

REPORT OF INJECTIONS OF FOREARM NEAR THE RADIAL AND ULNAR VESSELS —*Experiment* 51 —Cannula passed through small incision superficial to the radial vessels just above the wrist The mass was injected with considerable force, and on examination a superficial area 3 inches in length and 1 inch in diameter was found filled with the injected mass (NOTE —It is extremely difficult in injecting to know exactly the position the cannula occupies)

Experiment 52 —Injected posteriorly, *i. e*, dorsal to the radial vessels. The mass spread upward, and in the

section was found to lie on the radial side of the flexor pollicis longus, tearing the muscle to a great extent up to its origin. The mass had extended to the ulnar side of this vessel, a small part of it lying on the radial side between the bodies of the flexor digitorum profundus and flexor sublimis digitorum The greater portion had passed underneath the flexor digitorum profundus and filled up the area between this muscle and the bones with the interosseous membrane. It had extended to the ulnar side, lying in juxtaposition to the flexor carpi ulnaris, and at its distal end came to lie near the surface, *i e*, near the ulnar vessels It had extended distally between the tendons of the flexor digitorum profundus and the pronator quadratus It did not pass into the hand. It had extended *en masse* approximately to about 3 inches below the elbow-joint, and a small prolongation or isthmus extended along the median nerve above the elbow-joint for 3 or 4 inches into the arm, still lying close to the median nerve and consequently near the brachial vessels and accompanying nerves (NOTE —Out of six injections, more or less satisfactory, this extension occurred in two cases, suggesting why it is that, in deep infections of the forearm, loss of function of the muscles is so common, since both the blood supply and the nerve supply are impaired)

Experiment 53 —Results practically the same as Experiment 62.

Experiment 54 —Results practically the same as Experiment 1

Experiment 55 —Mass lay to the radial side of the arm above the flexor pollicis longus and to the radial side of the flexor digitorum profundus.

GENERAL CONCLUSIONS IN THIS SERIES OF EXPERIMENTS UPON THE RADIAL VESSELS —We have demonstrated that if an abscess should develop along the course of the lymphatic vessels, lying in juxtaposition to the

radial artery, it may be a superficial abscess which would point on the radial side of the arm If it follows the vessels farther it may spread to the deep tissues of the arm In other words, it may produce the same result as an extension along the interosseous vessels or a rupture from the ulnar or the radial synovial sheaths. It may extend to the ulnar side and lie immediately under the skin

EXPERIMENTS BY INJECTION ALONG THE ULNAR ARTERY.—As in the injections along the radial artery, these experiments are more or less unsatisfactory owing to the fact that there was always considerable doubt as to the exact position the tip of the cannula occupied, although the intention was to inject as close to the ulnar artery as possible, *i e*, to simulate the origin of a large abscess coming from the lymphatics and lying in juxtaposition to this vessel

In this series five injections were made at various sites, and demonstrated the tendency of such accumulations to come to the surface on the ulnar side early in the course If the injection were persisted in, the area of the forearm involved was first that between the flexor carpi ulnaris and the flexor digitorum profundus, then between the superficial and deep flexors, and then the area between the deep flexor and the bone, *i e*, the typical deep abscess of the major forearm space.

CHAPTER VII.

FUNCTION OF THE HAND IN RELATION TO INFECTIONS.

TOO often, we, as surgeons, look upon the hand only from an anatomical standpoint It is true that an adequate knowledge of the anatomy of the hand is essential, but the restoration of the hand to anatomical perfection is valueless without a proper conception of the physiology of the hand and how its functions may be preserved and restored From the very beginning of the treatment of an infection or injury the preservation of function must be kept constantly in mind, and adequate means employed to obviate its loss. To do this one must know the functions of the individual units as well as those of the hand as a whole and understand how these functions are controlled and carried out

The variations in the nerve supply and attachments of the muscles have made difficult any dogmatic statements as to their individual functions Moreover, one is surprised to find how little critical analysis has been given to such an important subject There is great variation in the description of the intrinsic muscles of the hand by anatomists Walsh, in his Boylston essay, has done much to clarify the question and certain neurologists and orthopedic surgeons have added much to our knowledge through clinical observations. The general surgeon to whom injuries and infections of the hand first come has, however, not given the subject the attention it deserves.

The primary actions of the hand are five: (1) Flexion of the fingers, (2) extension of the fingers; (3) adduction

and abduction of the fingers from the mid-line of the hand, (4) opposition of the thumb to the fingers, and (5) rotation of the hand. Supplementary to this are flexion, extension, adduction and abduction of the hand. When any one of these functions is lost the usefulness of the hand is impaired. The surgeon who gives adequate care to his injured patient must understand the basis of these various movements so that he may anticipate and prevent their impairment. Flexion of the fingers is carried out by contraction of the flexor tendons of the forearm, supplemented by action of the interosseus and lumbrical muscles which aid in flexion of the proximal phalanx. The action reaches its maximum efficiency when the hand is dorsiflexed and abducted at the wrist. One needs but to attempt flexion with the hand in volar flexion to demonstrate this clinically. This has been emphasized by Sir Robert Jones, and it is said by Steindler that three-fourths of the potential contractile power is lost when the hand moves from full extension to full flexion. Fortunately the hand is provided with exceptionally strong extensors so that the wrist can be fixed in dorsiflexion and permit the flexors to act at the greatest advantage. Dorsiflexion increases the passive tension of the flexors and thus increases the potential power. This position also relaxes the tension of the common extensors to the fingers and permits the passive tension of the common flexors, the interossei and lumbricales, to hold the proximal phalanges partially flexed and thus in a favorable position for the exertion of maximum power, since little or no power is lost by direct pull of the phalanges against the metacarpals. The same holds true of the other phalanges.

In the contrary position—volar flexion of the wrist—the function of flexion of the fingers is much impaired, since such volar flexion in addition to the loss of flexor power through the factors already mentioned permits

dorsiflexion of the metacarpo-phalangeal joints due to passive tension in the extensors now absent in the flexors and other muscles The proximal phalanges are over-extended and the pull of the flexors is handicapped—the fulcrum at the joint working at a disadvantage so that power is lost, pulling the phalanx against the head of the metacarpal bone rather than around it. This is the condition seen in an exaggerated form in the claw hand resulting from neglected tendon sheath infections and nerve injuries, and is a complication that must be anticipated and avoided If the action of the interossei and lumbricales is lost the long flexors must take over their flexor function, and this is done with difficulty, since they have no direct attachment to the proximal phalanges I have drawn attention to the tendency of infection in the palm to extend along the lumbrical canals and thus impair the lumbrical function in neglected cases and favor the development of the claw hand

The thumb is the most important digit The necessity of preserving it after injury has been appreciated by every surgeon, but the mechanism of its varied actions and the necessity of preserving the functions of its various muscles have not been emphasized as much as they should

The abductor pollicis brevis, opponens pollicis, and flexor pollicis brevis all take part in the important function of opposing the thumb to the fingers The action is complicated in that the thumb must be abducted and rotated, and if the flexor surface of the thumb is to come in contact with the flexor surface of a finger, flexion of the proximal phalanx and extension of the distal phalanx must take place The variable functions performed through this action, such as writing, threading a needle, picking up small objects, etc , calls for an infinite number of variations in degree of these individual actions Where any one muscle is impaired some function will be lost

The abductor pollicis brevis flexes the proximal phalanx and extends the distal phalanx, and in association with the abductor pollicis longus carries the thumb laterally as a straight rod, meanwhile the opponens rotates the metacarpal and hence the thumb At the same time the flexor pollicis brevis may extend the distal phalanx and flex the proximal, thus flexing the thumb as a rod For flexion of the distal phalanx the flexor pollicis longus comes into play The action of this muscle is influenced by the fact that the tendon is deflected from a straight line action by passing around the greater multangular bone at the wrist With the thumb abducted this gives a maximum power to flexion of the distal phalanx The short flexor and the opponens pollicis dominate flexion of the proximal phalanx. The interrelation of these with the extensors holding the proximal phalanx in extension and the fulcrum action of the greater multangular bone above mentioned give the long flexor a power of flexion of the distal phalanx out of all proportion to the flexion action of the distal phalanges of the fingers, an asset of great value in the prehensile power of the thumb opposed to the finger.

If the little finger is the one opposed the outer head of the flexor pollicis brevis acts more strongly, if the index finger, the inner head With varying degrees of action of the two heads the other fingers may be opposed

While the muscles above described are primarily involved in opposing the thumb to the fingers, it should not be forgotten that the muscles attached to the metacarpal may aid at least secondarily Extension of the phalanges and the thumb as a whole is aided by action of the extensor pollicis longus and brevis Abduction of the thumb with extension is supplemented through the action of these same muscles aided by the abductor pollicis longus Adduction of the thumb is performed by the adductor pollicis.

It would lead us too far afield to discuss the multiform and intricate actions of the individual muscles involved in other very necessary functions of the thumb and hand, such as making a hollow or scoop of the fingers and palm, playing the piano, etc

The function of the little finger is not of great importance in comparison with that of the thumb and other fingers, except in those individuals requiring complete digital dexterity as, for example, musicians The abductor digiti quinti and the flexor digiti quinti brevis supplement the action of the major flexors and extensors They are bound together anatomically and functionally The flexor digiti quinti brevis acting alone produces flexion of the proximal phalanx in a straight line The abductor digiti quinti is allied to an interosseus muscle, joins the common extensor and acts with it in producing extension of the distal two phalanges It extends the distal phalanx on the middle and the middle phalanx on the proximal, then may abduct the extended finger, or acting with the flexor brevis may abduct the finger, the proximal phalanx being flexed and the two distal extended

The opponens digiti quinti flexes the metacarpal of the little finger and rotates it slightly upon its long axis. By this action it aids in making a hollow of the palm and opposing the little finger to the thumb, acting in the latter case with the interosseus muscle

The intricate and very important functions of the interosseus and lumbrical muscles are not appreciated by the average surgeon Even the anatomists have not given to them the attention they deserve. Adduction, abduction, extension of the distal phalanges, flexion of the finger as a whole, opposition of the various fingers to the thumb, and cupping of the fingers are all carried out in large part by these very essential muscles They are interrelated in their actions When their functions are impaired by injury or infections, marked disability

ensues in all of the intricate movements so essential in writing, sewing, and the many other actions a part of everyday life The surgeon is culpable who treats infections and injuries of the hand with a reckless disregard of their great importance

Their anatomy and functions are better understood if we remember the embryological development of the hand Elsewhere, in considering congenital malformations of the hand, I have drawn attention to the fact that the hand originates in three elements One, the radial, gives rise to the thumb. A second, the ulnar, gives rise to the middle finger and from this anlage develop as secondary rays the ring and little fingers A third, the median, not well separated from the ulnar, gives rise to the index finger As a consequence of this embryological development the thumb has a markedly independent action, the middle, ring, and little fingers tend to functionate in unison, and the index finger, while coordinated with the other fingers, has a more independent action The coordinated action of the three ulnar fingers is expressed anatomically by the distal flexion crease of the palm that subtends their action The secondary coordinated action of the four fingers is expressed in the middle flexion crease The independent action of the thumb is seen in the proximal flexion crease

The distribution of the ulnar and median nerves and ulnar and radial bloodvessels, and the formation in the palm of the middle palmar and thenar spaces by a fascial septum attached to the middle metacarpal are expressions of the different origins of these parts of the hand. This is emphasized by the anatomy and actions of the interosseus muscles While anatomists describe them differently and it is admitted that the origin and insertion of these muscles is not always constant, yet a careful study discloses that this embryological origin from three anlagen has determined ulnar and radial elements sepa-

rated by an imaginary line drawn longitudinally through the middle finger, and that the index finger has interosseus attachments slightly different from the other fingers This in turn has determined slightly different function for the fingers. Of the three palmar interossei, the first has its origin on the *ulnar* side of the index metacarpal, while the second and third have their origins on the *radial* side of the ring and little fingers. As a consequence the first draws the index finger ulnarwards toward the middle finger and the second and third draw the ring and little fingers radialwards also toward the middle finger They pass anterior to the transverse axis of the metacarpo-phalangeal joint to join the common extensor tendons and send off filaments to the bases of the middle and distal phalanges Of the dorsal interossei, the first and second have their major origins from the *radial* side of the index and middle metacarpals, while the third and fourth have their major origins from the *ulnar* sides of the middle and ring fingers As a consequence the first and second draw the index and middle fingers radialwards, and the third and fourth draw the middle and ring fingers ulnarwards The little finger is abducted by its abductor acting as an interosseus In their insertion the second, third, and fourth accompany the distribution of the palmar interossei, but the first expresses the independence of the index finger by having its major insertion into the base of the proximal phalanx thus giving it greater freedom of movement

Their major functions are, therefore, adduction and abduction, but they also supplement the extensor action of the lumbricales upon the middle and distal phalanges with the exception of the first dorsal noted above

When one interosseus acts with the common extensor the finger is extended and drawn to one side or the other, toward or away from the imaginary line passing longitudinally through the middle finger, depending upon

whether a palmar or a dorsal interosseus is brought into play Adduction or drawing the fingers toward the middle finger is performed by the palmar interossei. Abduction from the middle finger and lateral movement of the middle finger itself are performed by the dorsal interossei. Flexion of the finger as a rod is brought about almost entirely by the interossei They extend the two last phalanges, possibly with help from the lumbricales, and then, by flexing the proximal phalanx, flex the whole finger

The lumbricales probably have the major share in the function of full extension of the two distal phalanges They fuse with the first and second dorsal interossei and the third and fourth palmar interossei Thus they tend to draw the fingers to the radial side It will be remembered that the first dorsal interosseus acts almost entirely upon the proximal phalanx, therefore, the burden of extending the two distal phalanges of the index finger falls almost entirely upon the first lumbrical

The interrelation of action of the intrinsic muscles of the hand with the extensors and flexors of the fingers is a most marvelous adaptation to complicated function and emphasizes the care surgeons should exercise in caring for injuries or infections, since the impairment of any one is of serious consequence The interossei and lumbricales, in attempting to extend the two distal phalanges, tend to flex the proximal, this tendency is overcome by the common extensor In grasping a large object the interossei abduct the fingers and with the lumbricales extend the distal phalanges aided by the common extensor. The latter now holds the proximal phalanx extended and the flexors overcome the extensor action of the interossei and lumbricales The extensors may to a certain degree substitute their action for that of the dorsal interossei, as is exemplified in ulnar paralysis in

which, with the fingers extended, the fifth finger only loses abduction completely, since in the little finger this motion is carried out by the abductor alone. With the fingers flexed, however, the abductor function of the extensors is lost A similar relation exists between the palmar interossei and the flexors It follows, therefore, that since for the sake of flexion function we must keep the fingers flexed during treatment, care should be exercised to see that the fingers are kept separated midway between adduction and abduction

The actions of the muscles involved in the movements at the wrist of the hand or the forearm are well known, it should be emphasized, however, that impairment of rotation (pronation and supination) produces serious disability, and especial care should be taken to preserve this function Take, for example, the simple act of carrying food to the mouth The turning of the hand necessary in the use of the fork is lost

The relation of function in various muscles to nerve injury will be discussed when that subject is presented

The preservation of the functions of the hand after infections and injuries is subordinated only to the preservation of life From the inception to the final stage of treatment the surgeon should have this in mind In the present contribution an attempt has been made to indicate where incisions for the evacuation of pus may be made with the minimum of danger to function Emphasis also has been placed upon adequate incisions and proper drainage with insistence that active and passive movements should be begun at the earliest possible period. With the greatest of care, however, it is often inevitable that a greater or lesser degree of impairment in function will occur With this in mind the hand should be maintained throughout the treatment in the position of function

THE POSITION OF FUNCTION.

The position of function in the hand is that in which the maximum power may be exerted with the least effort. Supplemental to this is the fact that in this position many important actions can be carried out with a minimum of motion (Fig 52)

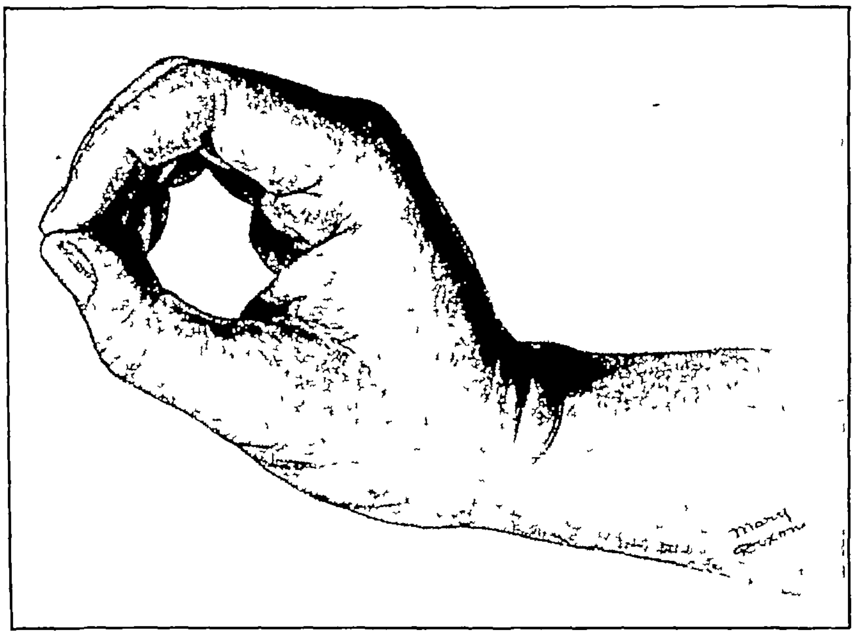


FIG 52 —Hand in the "position of function "

Bearing in mind the mechanics of action of the muscles it is evident that the most favorable position for function is that in which the hand is held midway between pronation and supination, dorsiflexed at the wrist, slightly abducted toward the ulnar side, with the phalanges all slightly flexed, and abducted so that the fingers are separated The thumb should be rotated and abducted so that the flexor surface of the distal phalanx is opposed but slightly separated from the flexor surface of the distal phalanx of the index finger An analysis of the observations made in regard to the functions of the various muscles will show that in this position a maximum power is imparted to the common flexors, and that

the phalanges are in a most favorable position for movement with the least effort, the disabling overextension consequent upon possible interosseus and lumbrical impairment being prevented.

The loss of the abductor action of the interossei is anticipated by the separation of the fingers The thumb being abducted and placed in opposition to fingers permits proper function even though only a minimum of action is possible.

If there is only a moderate degree of muscle and joint impairment the position of function favors rapid restoration to complete function since the strong common flexors easily overcome the contraction of the weaker common extensors Stretching of the interossei and lumbricales is easier than restoring contraction when their function is impaired The same is true in relation to the rotating action of the opponens pollicis and the abductor and flexor actions of the other intrinsic muscles of the thumb.

If there is a high degree of impairment of function even with partial ankylosis of the wrist and other joints, fibrosis of muscles, impairment of nerve function so that there is a minimum of motion possible, still with the hand in this position a large number of important actions can be executed, such as holding a knife and fork, picking up small objects, using a pen, taking the handkerchief from the pocket, and holding larger objects such as tools

The methods of maintaining the position of function during treatment will be presented in connection with the consideration of the treatment of infections The maintenance of this position and the restoration to it during convalescence and subsequent after-treatment will be considered in the presentation of the subject of physiotherapy and the description of the various tension splints we have devised.

CHAPTER VIII

GENERAL PRINCIPLES OF TREATMENT.

IT is not the intention here to discuss in detail the treatment of the various types of infections Specific directions for dealing with individual cases will be discussed in the chapters devoted to the different types It is proper, however, to deal with the general principles underlying the various procedures which might be scattered in the succeeding chapters

PROPHYLAXIS —Great care should be used in the preliminary treatment of minor as well as major injuries, especially in factories This subject is discussed in detail in the next chapter.

DECISION AS TO THE NECESSITY FOR INCISION — When a patient presents himself with an infection of the hand the surgeon should first consider whether it should be treated by conservative measures or by incision Hasty and ill-advised incisions may do serious harm It is better to err on the side of conservatism if the surgeon is in doubt as to the diagnosis of the type of infection. Many patients have lost their lives because of surgical incisions in lymphangitis and streptococcic cutaneous and subcutaneous infections Incisions in such cases should not be made except as a last resort or because of secondary abscesses On the other hand, delay in opening a tendon sheath infection will increase the probability of a necrosis of the tendon It therefore should be drained as soon as a probable diagnosis is made Fascial space abscesses are seldom so serious that injury will be done by waiting until the surgeon is certain of his diagnosis. The first duty of the surgeon is, therefore, to

make a differentiation between lymphangitis and streptococcic cutaneous and subcutaneous infections on the one hand, and tendon sheath infections on the other, meanwhile instituting conservative treatment such as voluminous hot moist dressings.

Incisions for Drainage —When incision has been decided upon certain rules are imperative. The operation should be done in a bloodless field. A Martin bandage applied from the elbow to the shoulder is to be preferred After the operation is concluded the bandage is loosened just enough to allow circulation, but still tight enough to prevent rapid absorption. In fact, I attempt to produce a Bier's hyperemia This is done with the hope of preventing the rapid absorption of toxins In a patient who is severely ill such rapid absorption may take place as to overwhelm the system before it has an opportunity to develop antitoxins or wall off the infection, while if the bandage is removed through the course of six to twenty-four hours the system may have an opportunity to develop antitoxins and ward off by leukocytic action a systemic infection that might ultimately lead to death Again, the patient should always be anesthetized. Nitrous oxide is the anesthetic of choice, owing to its non-toxic action This gives time for carefully placed and adequate incisions The surgeon should always convince himself before allowing the patient to awaken that he has done the work thoroughly so that the operation will not have to be repeated upon subsequent days This cannot be done under local anesthesia Moreover, the hypodermic injection of tissue about an infected area cannot be done without danger of causing a spread either locally or systematically

It has been suggested by some that in order to prevent rapid absorption and danger of generalized infection, it would be advisable to open abscesses by the cautery, and again others have suggested painting the cut edges with

some solution of iodine Against this method it has been urged that the cauterized wall will seal up the bacteria and toxins, since serum drainage is prevented, and as a consequence the patient is in greater danger of systemic infection or prolonged local disturbance It is my personal belief that any procedure which impairs the vitality of tissue-cell life, thus reducing its resistance and reparative powers, will be discarded in the end. In the fulminating and gangrenous infections, however, the incisions and removal of gangrenous sloughs is probably best done with the radio knife

Drainage.—Drainage of wounds by means of gauze, tubes, etc, is not of the importance attributed to it by some The essential factor is to make the incision at the right place and of adequate size If this is done, drainage strips will be not only unnecessary after the first forty-eight hours, but often positively detrimental to recovery. After incision it is my custom to use either plain gauze, gauze saturated with vaseline, or rubber strips The former is used only when there is venous oozing and we desire to stop it by favoring coagulation We must never expect it to do more than this, and keep the edges of the wound separated, for the plain gauze mesh is soon filled with pus and coagulated serum, which acts as an effectual bar to drainage Where there is no bleeding, gauze strips thoroughly saturated with vaseline or rubber strips are used These secure adequate drainage, and can be removed without pain They are left in for twenty-four to forty-eight hours, if left in longer they prolong the suppuration It has happened to every surgeon to see cases in which the wound has been kept open for weeks by ill-advised drainage material Except where the Carrel-Dakin method is used rubber tubes are never used, since they favor tissue necrosis and are not any more satisfactory for drainage than rubber strips Spring separators made of wire may be used to keep the wound open.

The common habit of pressing and squeezing wounds with the purpose of forcing out the contained pus cannot be too severely condemned It is both unnecessary and harmful If adequate drainage is made, the pus free in the abscess will drain out, and if it is in the layers of fascia adjacent to the wound, pressure is just as likely to force it farther into the tissue as into the abscess cavity. If the opening is small and drainage inadequate because of the thickness of the pus, the wound should be opened more widely If the opening is plugged by seminecrotic connective tissue, it may be removed by the forceps, never with a sharp curette To repeat, the pressure and squeezing tend to disseminate the infection throughout the surrounding tissue and even produce systemic infection or dislodge septic thrombi

After almost all incisions in virulent cases there is severe local reaction, causing more swelling in the first twenty-four to thirty-six hours At the end of that time, if the process has been properly drained, the swelling and temperature should begin to subside

The surgeon should be constantly on the watch for extensions of the infections In the chapters dealing with the various types attention has been drawn to the probable sites of secondary abscesses

Asepsis in Subsequent Dressings —In subsequent dressings the greatest of care should be exercised not to contaminate the wound with other types of organisms. The synergistic action of various bacteria is very harmful. Sterile instruments should be used in dressing the wound and every effort made to maintain an aseptic technique

Rest —Rest is one of the essential factors, at least in a negative sense The extremity affected should always be so fixed that movement, either of the whole or muscular action of a part, is impossible, since it is well known that lymphatic streams are aided materially in their return flow by muscular action It will undoubtedly

relieve the patient somewhat of the throbbing pain to have the hand elevated after the von Volkmann method, but beyond that I cannot feel that this procedure is of great therapeutic value The patient should have sleep and, if necessary, morphine or other sedatives must be administered

INCREASING THE PATIENT'S RESISTANCE —Positive factors designed to increase phagocytic action are still subject to discussion, in spite of the extensive contributions in support of this or that procedure They may be classified as systemic and local The local again are divided into the results of active hyperemia and of passive hyperemia

Drugs —The systemic use of drugs, such as nucleic acid, etc , to increase leukocytosis, has never been followed by such marked and positive results as to prove beyond question the advisability of their use, and all, so far as known, may ultimately be discarded, as was turpentine which preceded them They have never given any results in my hands We are not now discussing the applicability of drugs and sera in systemic infections That will be taken up when considering that subject

Passive Hyperemia —Among the local procedures, those producing passive hyperemia (Bier) have received the greatest attention in later years While much of an enthusiastic nature has been written in favor of this method, it is probable that the American surgeons have not secured the results claimed for it by its German supporters It is not the province of such a contribution as this to review the subject, with a discussion of the various theories as to the changes in the blood, the lessened resistance as claimed by some and the raised opsonic index as maintained by others My personal opinion has become quite settled as to its value in acute infections I have found its chief value in three conditions First, where I wish to prevent the rapid absorption

of toxins into the circulating blood, as, for instance, in an acute lymphangitis, second, immediately after incising virulent abscesses of the hand and arm where a marked constriction will reverse the lymph stream and tend to wash the toxins out into the wound, preventing absorption, third, in those cases in which the process has become semichronic with a low grade of infection.

Beyond these conditions I look upon it as a possible adjuvant in the treatment, but never as the primary factor It follows, therefore, that early in the course of an infection, if we suspect the process to be particularly virulent, a Martin bandage may be applied lightly to the arm, and gradually loosened Any other method is painful and may even be harmful In the ordinary cases I have contented myself with other means, namely, hot moist dressings, the use of which it would appear rests upon a more rational basis Klapp has emphasized the value of suction cups used over a localized infection He has devised various types to fit various areas Their value in certain conditions cannot be gainsaid, particularly in those cases which would be classified in the second and third groups above

Hot Moist Dressings and Allied Applications—These are in common use by all, and have proved beneficial in many cases The most common form in which they are applied is that of the saturated hot boric acid solution, although many other medicaments are employed, such as potassium permanganate, alcohol, bichloride, etc. The solution of hot boric acid, in my opinion, depends for its efficiency largely upon the moist heat, although scientific evidence is not wanting that its chemical action may be of some value In this connection Dr E H. Ochsner reports that Professor Kakenberg, at the University of Wisconsin, conducted a series of examinations demonstrating the presence of a small amount of boric acid—0 01 to 0 03 per cent—in urine voided after hot

applications of a saturated solution of boric acid in water, 3 parts, and 95 per cent alcohol, 1 part This is not the occasion to discuss the question as to the bactericidal effect of boric acid, especially in small percentages. Other investigators have maintained that a large percentage is found in the skin and subcutaneous tissue. The dressings may be applied as follows The saturated solution is boiled and then set aside, and, as it is desired, it is heated to as great a heat as can be borne by the bare forearm of the attendant Greater heat, as demanded by some, is not needful The patient should not be left to decide "if he can stand it," since the infected hand is often very insensitive to superficial pain, and the inadvertent application of the excessive heat may lead to blisters which will be annoying and prolong convalescence After the desired temperature is secured a sterile towel is unfolded, the dressings are dropped into it, and it is then immersed at its middle in the solution The dressings are wrung dry by turning the two dry ends in opposite directions, thus securing the dressings properly saturated and wrung out, but still sterile The arm is now laid on a sterile towel and the dressings applied widely (Fig 161) Fear rather that your dressing may be too small than too voluminous In any extensive infection we always envelop the entire arm to the shoulder The whole is covered by some impervious material, such as paper saturated with paraffin or rubber sheeting This should be covered by a layer of cotton followed by a bandage, or enveloped in a towel Provision should be made at the time of dressing for subsequent introduction of the solution by inserting two perforated rubber tubes into the gauze pack. To these is attached a Y tube outside the dressing through which, by means of a funnel, warm boric acid solution can be introduced aseptically every two hours The heat is maintained by placing the arm

in an electrically heated chamber, exposing it to electric bulb heat or by the use of hot-water bottles

Too often we see the hot boric acid continued for several days It is not only useless but harmful to continue this treatment after the process is once under control, since it tends to favor congestion and round-celled exudation, which, if long continued, produces a soggy, infiltrated hand in which absorption is slow, and as a consequence the ravages of the disease are slowly repaired and fibrinous ankylosis of joints, adhesion of the tendons, shrinking of muscles, and fibrosis in all the various structures are favored

As soon as the process has subsided the infected hand may be treated in various ways, according to the condition In the presence of congestion, a dressing saturated with a weak solution of alcohol or equal parts of alcohol and glycerin will aid in the dehydration If there is a foul discharge, a 1 to 2000 potassium permanganate dressing is advisable If there are many raw surfaces requiring dressing, the gauze may be saturated with vaseline, which permits of painless dressing and does not retard drainage Against alcohol may be urged with justice its inflammability, so that it should always be used with care One case came to my notice in which the patient was severely burned through its use

Bacteriophage.—D'Herelle, who introduced this method of treatment, believes that during convalescence from septicemia and all infectious diseases, a lytic or bacteriophagic principle appears which has the power to destroy the pathogenic bacteria concerned in the production of the infection He believes the bacteriophage is in the form of corpuscles about 10 millimicrons in diameter and that they act upon the bacteria by a ferment that they secrete

When used it must be prepared by reliable methods

and destroy specific organisms *in vitro*. It is generally best to prepare the bacteriophage from the patient's own bacteria It may be used locally or by subcutaneous injections. If the latter, three to four injections are given at twenty-four hour intervals and at some distance from the focus of infection. A greater number of injections will sensitize the organism and aggravate the infection When the lesion is accessible the bacteriophage may be applied to the infected area on a dressing, but should be supplemented by injections It is applied to all types of infections, but the staphylococcic seems to be most intractable

French, Italian, and German surgeons have shown much interest in its use Some critical analyses by American surgeons have failed to support the extensive claims of D'Herelle While I have used it, my experience has not been sufficient to pass judgment upon its value

Stimulation of Excretions—The excretions should be stimulated, particularly by the introduction of large amounts of water into the system. This may be done by mouth, by rectum, or intravenously, according to the conditions to be met If introduced by rectum, ordinary tap water has been more satisfactory than normal salt solution since it is better borne by the patient and relieves his thirst more quickly

The subcutaneous administration of water is not advisable since, if the patient is so ill as to demand subcutaneous or intravenous introduction, there is generally some septicemia and, in the presence of this, a secondary localization may occur at the site of the subcutaneous injection

Nutrition—The patient should receive easily digested food. This is best given in small amounts at frequent intervals and in a liquid form. In severe infections the intravenous administration of glucose solution may be indicated

Dehydration of the Hand—After the spreading tendency of the infection has been controlled by hot, moist dressings it is well to dehydrate the hand by exposure to sunlight or the heat of an electric light. At first this may be done for an hour or two, twice to three times in twenty-four hours, dressing the hand with a light dry covering in the intervals This tends to lessen the edema and to decrease superficial bacterial growth. Auchincloss was one of the first to make an extensive study of the value of baking the hand in dry hot air I have frequently drawn attention to the value of exposure of infected areas to sunlight. Where this is not available ultra-violet rays may be used under strict professional supervision so as to prevent burning of the sensitive skin

Exposure of the Whole Body to Sunlight or Ultra-violet Rays—In addition to the local exposure which is used only for its dehydrating and bactericidal effects, the exposure of the entire body to sunlight or artificially produced ultra-violet rays has undoubtedly a beneficial effect in increasing the patient's resistance and overcoming infections, particularly those in a chronic stage. Care should be used not to expose the body too long in the daily treatments. The skin reaction should be determined by short treatments for the first few days, fifteen minutes to an hour if sunlight is used and from one-half minute to a minute for various parts of the body if ultra-violet rays are administered The dose is increased daily as the resistance of the skin is established

Blood Transfusion—In exceptionally toxic cases and in patients suffering from debility and lowered resistance incident to long continued infection, blood transfusion is of great value It should be repeated as often as necessary The blood types of the donor and recipient should be determined and only the proper grouping used

PLACING THE HAND IN THE "POSITION OF FUNCTION"—During the course of treatment the hand, wrist, and

fingers should be placed in the position of function—should treatment be prolonged this favors early and satisfactory use and prevents fixation in positions favoring disability The fingers should be slightly flexed, the hand extended in the "cock-up" position, the thumb abducted and rotated so that the flexor surface of the thumb is opposite the flexor surface of the index finger—with the hand and fingers in this position, even though tendons may be lost or ankylosis ensue—a fair degree of function will be secured (Fig 52).

Delayed Recovery—The ordinary infection of the hand if treated promptly and efficiently should make a rapid recovery The question of amputation in gangrenous cases is discussed when dealing with that subject. If recovery is delayed the surgeon may find that a systemic cause, such as diabetes, syphilis, or nephritis is present, but in the great proportion of cases it will be found that the cause lies in the presence of necrotizing tendons or osteomyelitis These complications should be watched for constantly It is surprising how quickly an infection that has persisted for some weeks will be controlled by the removal of a necrotic tendon Any tendon showing fragmentation or necrosis should be removed promptly. Conservative treatment with an incision for drainage may be used in the early stages of an osteomyelitis, but gross death of bone must be followed by radical surgery.

If the necrotic tissue is superficial or can be reached by fluid, Dakin's solution properly applied is of material benefit Care should be used, however, not to introduce it over non-necrotic tendons, since it may favor their destruction

At times we see recovery retarded by the persistent use of drainage material

Physiotherapy—The surgeon should keep constantly in mind not only that the infection should be controlled

but that the function of the hand must be preserved Physiotherapy should be instituted at the earliest possible moment The determination of this time calls for some judgment. In general it may be stated that as soon as the surgeon believes the danger of spreading the infection has ended, passive and active motion should be begun, followed some time later by massage This subject is considered later in a special chapter

CHAPTER IX

PROPHYLACTIC TREATMENT OF INJURIES

A Consideration of the Methods of Preventing Infection After Accidents, and the Prophylactic Care of Employés in Industry

WHILE the principles of the prophylactic care of injuries are no different in civil and industrial life, yet the latter present problems in the group care of patients and the relation of disability to compensation laws that call for special consideration In either the primary treatment may be different, depending upon whether or not immediate competent surgical care is available For instance, if such care is at hand, wounds should in most instances be cared for aseptically without the use of antiseptics such as iodine, if not, the use of such prophylactic measures are advisable

A large proportion of the infections of the hand follow trivial injuries such as needle pricks, injuries with slivers of wood, and minor scratches and punctures Most of these infections could be prevented by efficient first aid This includes forcing drops of blood out of punctures with the prompt application of hot moist dressings, proper care of simple wounds by cleansing or the application of tincture of iodine, removal of foreign bodies aseptically, and immobilization in case of doubt The relation of debility and concomitant infections is brought out later in discussing the relation of these to infections among employés There also is emphasized the advisability of hospitalization in the incipient stage of infection

Concerning the best method of caring for the major injuries there is a great divergence of opinion With increasing experience we have come to lay greater stress

on careful thorough cleansing of the wound with soap and water, and abstinence from the use of powerful and irritating antiseptics, because of the destructive action of such antiseptics on exposed and non-resistant tissue cells

In such injuries it is our practice to remove gross dirt and foreign material from the wound with sterile instruments and gentle irrigation, lay sterile gauze over the wound itself, and wash the area about the wound as carefully as possible with soap and water If covered with hair a wide area of skin about the wound is shaved If the wound is one in which complete débridement can be carried out, the wound itself for the preliminary cleansing mentioned above is left untouched until the actual débridement is performed If débridement cannot be done, the wound itself is finally cleansed as thoroughly and as gently as possible with soap and water on sterile gauze sponges If grease and dirt cannot be removed with soap and water, ether, benzine or some other fat solvent is used, followed again by soap and water Tincture of iodine, mercurochrome or other antiseptic solutions other than soap and water are not used on the open wound at the time of operative treatment As a prophylactic at the time of injury when immediate surgical treatment cannot be given, tincture of iodine may be applied

Complete débridement, if it can be performed without sacrifice of essential structures, is the ideal procedure. If devitalized tissue can be completely removed, and the wound converted into a clean wound, wound closure is a logical procedure if not more than three hours have elapsed between the time of injury and operative care Such closure may involve the use of a sliding flap, a flap from a distance, or a free graft If a sliding flap is used, a thin graft may be necessary to cover the site from which the flap is raised (Fig. 53).

If a complete and satisfactory dêbridement cannot be performed without loss of essential tissue, a paramount consideration is to guard the patient against infection which may be left in the wound in spite of efforts to cleanse it. With this in view it is important to avoid introduction of any foreign bodies or foreign material into the wound If bones are fractured the fracture is reduced, but no plates, pegs, screws, or other foreign material are used to maintain reduction Bone fragments which are free are removed, but fragments which have

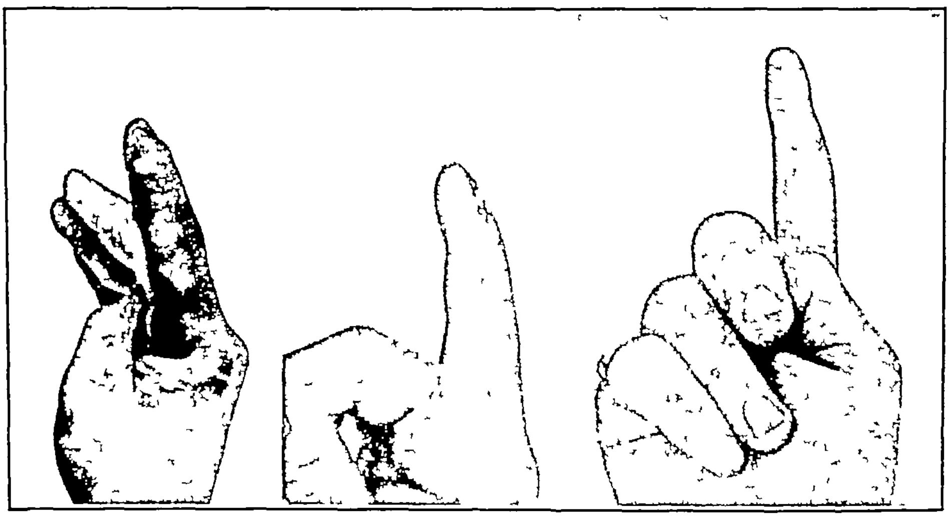


FIG 53 —Full-thickness skin graft applied to finger immediately after loss of the lateral half of the distal phalanx from accident, followed by prompt healing without infection

an attachment to periosteum or muscle are replaced as accurately as possible Divided tendons and nerves are left untouched except in those instances where the surgeon is certain of wound healing by primary union and without infection Unless one is certain that the wound is free from infection it is wiser simply to close it loosely, or to leave it open and perform secondary closure in three to four days, than to run the risk of spreading infectious material by the dissection invariably necessary for satisfactory nerve or tendon suture. We are, how-

ever, in these cases of delayed suture in the habit of attaching the ends of the divided nerves by a simple retention suture at the time of the primary treatment, so that final nerve suture is facilitated Drainage should be inserted only in cases where bleeding cannot be controlled or excessive wound secretion is probable Even in these cases it is generally wiser to provide for this by loose suturing rather than by the insertion of drainage material

The value of immobilization after operation must not be forgotten. No surgeon would fail to immobilize a limb if a fracture had occurred; one often fails to remember, however, that after an extensive injury of the soft parts, immobilization prevents pain and favors healing just as it does in the presence of bone injury

During the immediate postoperative period one must constantly bear in mind the possibility of development of infection Local signs of inflammation and a rising temperature indicate the necessity of opening the wound, if it has been loosely sutured, and applying a large, warm, wet dressing A culture and smear of the wound secretion at the end of twenty-four hours often give definite and helpful information

Where infection with tetanus bacilli is possible this should be anticipated by the administration of tetanus antitoxin at the time of operation The possibility of infection with the organisms of gas gangrene must likewise be kept in mind, and the wound examined for signs of such infection at least once in twenty-four hours, even though the patient is free from fever and pain The symptoms of anaerobic infection which leads to gas gangrene deserve especial emphasis, for the successful treatment of anaerobic infection depends upon its early recognition and upon the promptness with which adequate treatment is carried out.

The presence of a wound discharge with an unpleasant

odor should at once suggest the necessity of a microscopic examination and bacteriologic culture of the wound secretion The presence in the smear of large, Gram-positive bacilli with square ends, some of which may contain spores, is sufficient to make a diagnosis before the clinical symptoms are well-developed. To wait for clinical symptoms often mentioned as diagnostic of gas gangrene —the presence of bubbles of gas in the wound secretion, crepitus of the soft tissues about the wound, and the roentgenologic demonstration of gas in the tissues—is to wait until the most favorable moment for treatment is passed, and until successful local treatment can no longer be carried out

The surgical treatment of a wound in which gas gangrene is probable, or has developed, is discussed in the chapter on Gangrenous Infections, and need not be repeated here The importance, however, of remembering the possibility of infection with virulent anaerobes in every compound injury, and particularly in injuries sustained on the street and about stables, cannot be stressed too often

Infections due to human bites and fist fights invariably cause necrosis of tissue and a foul smelling wound discharge Such infections may be as serious and rapidly progressive as those due to the common anaerobes, but the infection in such cases is due to the many and varied virulent organisms constantly present in the human mouth

In the presence of wound infection with pyogenic organisms our first obligation is to secure free drainage by opening the wound widely, and to bring about localization of the infection Various methods to attain this end have been advocated from time to time We have had little experience with the majority of these methods, but have seen many of them attain a vogue for a time and later fall into disuse with returning realization of the

fact that Nature has through the centuries envolved a superlative method of combating infection, which consists essentially of a mobilization of all the defensive elements of the body at the site of invasion, and that the most helpful thing one can do in combating infection is to carry out measures that aid in the mobilization of these defensive elements and favor their activity, and avoid measures that retard their activity Phagocytes, other leukocytes, blood serum with its antibodies and food content for living tissue cells, red blood cells with oxygen for oxidation of the carbohydrates all play an important part in warding off the bacterial invasion. The application of warm wet dressings produces an active hyperemia with mobilization of these natural defensive forces Cold applications have the opposite effect and their use is contraindicated in the presence of spreading infections. Elevation of the affected part favors the return circulation and so helps to prevent congestion Immobilization should be maintained and the patient placed in bed for complete rest Elimination of toxins is favored by the administration of large amounts of water.

We have not seen sufficient evidence of the value of antistreptococcic and antistaphylococcic sera in the treatment of such infections to justify us in urging their use We have given a standard commercial antitoxin for bacillus aerogenes capsulatus and vibrion septique in cases of gas gangrene, and believe it to be of real value Whether the use of bacteriophages will justify the expectations that have been held out for them, time will decide

When the infection is localized the use of Dakin's solution is helpful in hastening the process of wound sterilization, chiefly, we believe, by its solvent action on necrotic tissue

Of very great importance in minimizing infection is the employment of aseptic technique in dressing the wound If one can consistently avoid adding infection from with-

out, *i e.*, from the hands of surgeon and nurse, from the patient's skin, and from soiled dressings and instruments to open wounds, a very great handicap to the process of wound sterilization is removed.

When extensive infected wounds have become surgically clean the question of maintaining asepsis and bringing about healing in the shortest possible period of time deserves consideration Too often the surgeon is willing to wait for raw surfaces to heal spontaneously, forgetting that time, money and function may be saved by hastening the process of healing with the use of skin grafts To bring about healing in the shortest possible time, to eliminate the danger of reinfection which remains as long as an open wound is present, and to keep scar tissue formation at a minimum is good surgery The use of thin grafts or of pedunculated flaps to bring about this result is indicated not only when other measures have failed, or when the process of spontaneous healing comes to a standstill, but in practically every instance in which a surgically clean raw surface more than 1½ to 2 inches square results from loss of tissue following a compound injury

THE RELATION OF INFECTIONS TO ACCIDENTS IN INDUSTRY

The "safety first" movement which has swept over the country during the last few years has brought most forcibly to the employer, the employé, and above all to the company surgeon the importance of preventing accidents, or, if they occur, to treat them promptly and efficiently In fact, the pioneer efforts along these lines of a few company surgeons really mark the beginning of this great movement. Among these is Dr Harry E Mock, to whom I am indebted for much of the data here detailed relative to this subject Many paragraphs are quoted *verbatim* from his various contributions

Insurance companies and industrial accident boards state that hand infections cause a high percentage of their disabilities Varying with the industry, this percentage will run from 5 to 25 per cent It is probable that from 7 to 9 per cent of all total disabilities are due to hand infections, and statistics show that from 50 to 65 per cent of these develop from minor injuries Chase states that the records of the Industrial Accident Board of Oklahoma show that in 60,583 partial disabilities, 20 per cent were due to injuries and infections of the hand, and that in 884 complete disabilities 58 per cent were due to the same cause The percentage of these due to primary infection will vary with the type of work performed A stockyard plant in Chicago reports that 75 per cent of their hand disabilities follow infections, and a large accident insurance company states that 20 per cent of their total hand disabilities arise from the same cause.

Minor injuries such as scratches, abrasions, pin pricks, nail and splinter wounds, etc , have proved most difficult for industrial concerns to prevent, and it devolves on the company surgeon to prevent infections from developing in these slight wounds, or if infection has already developed to treat it so thoroughly and actively as to prevent prolonged loss of time from work, loss of function in a member and, above all, death

In the winter months, when tonsillitis is most prevalent, hand infections among employés have been found to be correspondingly more frequent A number of these hand infections have been due to the action of a hemolytic streptococcus, and have either been associated with or followed an attack of tonsillitis A careful bacteriological study of a series of these cases resulted in finding the same hemolytic streptococcus as the cause of both the tonsillitis and the hand infection The following table shows this relationship Note the increase in hand infections with the increase in tonsillitis.

From a working force of 11,000 employés.

January and February, 1913 Total number of cases of tonsillitis 327
January and February, 1913 Total number of cases of hand infections 83
Total number of days of disability from hand infections 63
Number of hand infections having tonsillitis at the time or just before infection developed 15, or 18 per cent

In 1914 we had in Chicago a serious epidemic of tonsillitis, usually of the streptococcic type

From the same working force

January and February, 1914 Total number of cases of tonsillitis 603
January and February, 1914 Total number of cases of hand tions 117
Total number of days of disability from hand infections 208
Number of hand infections having tonsillitis at time or just before infection developed 32, or 27 9 per cent

In 19 of these cases the hand infection was very severe, with lymphangitis and extensive tenosynovitis Twelve of these were due to a hemolytic streptococcus, and the same organism was found in the patients' tonsils Twelve others had a marked lymphangitis, and while the organism was not ascertained, yet these were undoubtedly streptococcus infections and closely related to the tonsillitis

The chief contributing factors to hand infections noted among industrial employés are

1 Failure of employé to report to doctor for suitable dressing immediately after the injury is received minor accidents are more frequently infected

2 Too much dependence on a first-aid outfit and an emergency man Many cases are treated by the first-aid emergency man which should be sent to a surgeon at once, instead of waiting until the infection has developed

3 The fellow employé as a first aid Too often a kindly fellow employé will remove a splinter with a dirty knife or pin, or will apply some homely remedy to a cut or nail wound, whereas if these services were not offered

the injured worker would have consulted the surgeon at once Remedies commonly used by such employés are tobacco that has been chewed, or washing out the wound with hydrogen peroxide or tap water and then applying a rag or waste which is far from sterile.

4 The anemic, undernourished, or run-down individual, or the person who works in an ill-ventilated space and takes very little outdoor exercise is far more prone to infections Faulty home conditions, such as overcrowding, sleeping in bedrooms with poor ventilation, have frequently been found on visiting these infected employés.

5 Packers, porters, resturant workers, such as waiters and dish-washers, garment workers, inside truckers, filing girls, stenographers, clerks and office workers are more prone to hand infections than machinists and outside workers such as carpenters, masons, gardeners, teamsters, railroaders, etc

PREVENTION OF HAND INFECTIONS IN INDUSTRY

Education of both the employer and the employé is necessary to remove the causes found in the working place As an example The lining of bins which had become loosened was the frequent cause of injuries which became infected In every case, a notice was sent to the manager, pointing out the preventable nature of this accident, and in one year the injuries from this source were reduced from 75 to 10 The same procedure was then followed in the case of broken baskets, exposed ends of wire, nails on the floor, pins in packages, etc , all resulting in a decrease in minor accidents and therefore in infection The employés were carefully instructed concerning the dangers of these minor injuries, and were urged to remove any causes for such injuries which they found during the course of their work

The removal of causes for infections found in the employé is a part of a vast field of preventive medicine

and preventive surgery among industrial workers Thus, the discovery of the diseased employé by a periodical medical examination of all employés is a valuable adjunct to any system of prevention By proper advice many of these diseased conditions can be overcome, a change of work may be indicated in other cases, and the regulation of the employé's mode of living, both at work and at home, and as regards outdoor exercise, will correct a great many of the anemic, undernourished and run-down conditions In girls we frequently see recurring infections in the same individuals A study of these cases will reveal a marked anemia, the correction of which overcomes their tendency to infections The relationship of tonsillitis to infections has already been mentioned The removal of the tonsils when diseased, therefore, would not only stop the sick disability and the spread of the disease throughout a department as an epidemic, but would be a great preventive measure against infections

Prohibiting employés from removing splinters or in other ways from promiscuously rendering first-aid to fellow employés is another great means for prevention

The immediate treatment of all minor injuries is the surest means of preventing an infection from developing. Naturally, the safest agent to render this treatment is the trained surgeon A well-trained nurse is the next best substitute for the surgeon In the absence of both a doctor and a nurse, a carefully instructed first-aid man, chosen from among the employés and furnished with a proper first-aid kit, may render this immediate treatment to the injured employé With very few exceptions, it is always safer to send these minor cases to a surgeon as soon as possible, even though a nurse or first-aid man has given them immediate care

A very important factor in the prevention of infections is a suitable emergency office where prompt, aseptic surgical treatment can be rendered If this service is

available the prophylactic use of antiseptics, such as iodine, is not indicated, but in case of doubt or where the employé incurs scratches or abrasions and does not apply to a surgeon, iodine should be applied

Where immediate surgical care by a surgeon is not available *tincture of iodine* is the greatest protection against infection that can be used Every such industry should supply each department with a bottle of tincture of iodine and another bottle containing applicators, and should instruct each employé in its use. The importance of this should be pointed out to the department foremen again and again, in order that they may instruct each new employé as to its value In 1909, impressed by the great number of hand infections reporting to the doctor's office in a large industry, Mock installed this use of iodine as a preventive measure Immediately, there was a reduction of 38 per cent in the number of infections Practically all of the infected cases failed to use iodine at once. The following figures taken from a report show the importance both of using iodine and of reporting to the doctor at once for dressing

From 3000 accidents, 44 per cent reported at once, and 41 per cent used iodine at once, 43 per cent reported late and failed to use iodine, the remainder were cases where its use was not indicated. From the above number there were 654 infections, 12 of these used iodine and reported at once, 24 failed to use iodine, but reported at once, 618 reported from one day to one month after receiving the injury, with the part infected, of this number, 40 per cent used iodine somewhat later, while 60 per cent failed to use it at all

The 36 infections that used iodine or reported immediately were all very slight and did not require opening, while 440 of the group who failed to use it or reported late required incisions, thus necessitating 1912 days of disability and further decreased efficiency by working with

a finger or hand bandaged for several days A large percentage of these cases occurred among new employés

The importance of early reporting to the doctor for a dressing is demonstrated not only by the above figures, but by the fact that major injuries, which force the employé to report at once, seldom become infected

The use by employés or nurses of hydrogen peroxide, bichloride wash, or even soap and water on a fresh wound is never indicated Hydrogen peroxide especially, by its foaming, expansive power, carries dirt deeper into the wound without killing the germs of infections. Even in the use of iodine, the effort is not so much to cleanse the wound, as to inhibit the growth of any germs that might have been introduced.

ACTIVE TREATMENT OF HAND INFECTIONS AMONG EMPLOYÉS

When an infection has once developed, the best medical treatment is at times the most expensive, but in the long run it is the most economical. Too often, a doctor hopes to save his patient loss of time, or, if he is a company surgeon, he hopes to treat the case and still keep the patient at work thus the surgeon adopts what at first seems the most economic line of treatment, but by so doing frequently temporizes with the infection

In dealing with this subject from an economic viewpoint, it is not the actual cost of medical services which is referred to, but the actual economy to the patient and to the concern for which he works The most perfect line of treatment must give

1 The shortest disability, with a minimum amount of suffering, and the fewest hardships to those dependent on the patient.

2 It must prevent permanent deformities, such as loss of function, or loss of fingers

3. It must reduce the death-rate to a minimum.

In 1600 cases of hand infections studied by Mock, a major part were the result of minor accidents such as the following, named in their order of frequency: Pin pricks, splinters, abrasions from baskets, boxes, bins, etc., lacerations from knives, scissors, and other sharp utensils, bruises and contusions, nail wounds, scratches from tin and wire. The greater number of these infections were very slight causing no loss of time from work, and requiring from 3 to 10 dressings. Nevertheless, there was a certain disability connected with them, as an employé with a bandaged finger or hand has less working capacity than an unhampered employé. Therefore, reduction in the total number of infections means a marked saving in this form of disability. It has been further reduced by careful attention to the simplest, yet adequate, dressing which can be applied. A certain number of the above infections became serious, requiring considerable treatment either at home or at the hospital, and caused an actual loss of time from work. Thus, the 1600 cases may be classified as follows:

(*a*) Mild, or causing no loss of time, 1189, or 74 per cent.
(*b*) Serious, or causing loss of time, 411, or 26 per cent.

In order to arrive at the best and most economic treatment of these hand infections, it is necessary for us to study the 411 cases mentioned above which were serious enough to amount to actual disability.

One of two plans of treatment was adopted in every case of hand infection, namely, ambulatory treatment or hospital treatment. The ambulatory care consisted in opening the infected part at the doctor's office and allowing the patient to go home, reporting to the office for subsequent dressings. Frequently a local anesthetic was used in operating on these infections, but a general anesthetic was never administered in the doctor's office. When necessary, instructions were given to the patient as to the use of hot dressings at home, and nurse would

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call to see that these instructions were carried out Naturally, these infections were not so serious as those given hospital treatment, but in spite of this fact their average disability was greater The absolute rest obtained by hospital treatment would cause more rapid recovery of these cases, but the idea of going to a hospital for a small, minor infection does not appeal to most patients

When a hand infection showed signs of becoming serious, or threatened complications were apparent, hospital treatment was insisted upon. Here the infection could be opened under a general anesthetic of nitrous oxide gas, and the patient kept absolutely quiet in bed, with continuous hot, moist dressings applied until the acuteness of the condition had subsided. Likewise, many cases of threatened serious infection could be aborted and the necessity of opening these overcome by sending the patient to the hospital, giving him absolute rest in bed, preventing the movement of the infected part, and applying continuous hot packs for twenty-four to forty-eight hours.

Ninety-five per cent of the infected hands requiring two or more operations occur in those cases given office treatment The accompanying analysis of the serious cases demonstrates the great advantages of hospital treatment for hand infections as compared to ambulatory treatment.

AMBULATORY VERSUS HOSPITAL TREATMENT OF SERIOUS HAND INFECTIONS

	Treated at doctor's office and at home	Treated at hospital
Total number	253	146
Opened	210	78
Not opened	43 or 17%	68 or 46 5%
Total loss of time from work	2790 days	1088 days
Average loss of time, per case	11 02 days	7 4 days
Permanent disability, as loss of function or member	0	2[1]
Deaths	0	0

[1] 25 per cent loss of function by stiff middle finger 10 per cent loss of function by stiff thumb

A study of the above facts demonstrates that *dangerous infections can be prevented and disability reduced by the early adoption of hospital treatment.*

There were 12 very serious, complicated cases of hand infections from this series which are not included in the above table, as these were first given home treatment, usually by their family physician, and later, as a final resort, came under our care at the hospital The serious results of this delayed treatment are conclusively demonstrated by the following chart:

SERIOUS COMPLICATED CASES TREATED AT HOME AND TAKEN TO HOSPITAL AS FINAL RESORT

Total number		12
Opened		12
Total loss of time from work		379 days
Average loss of time, per case		31 5 days
Permanent disability, loss of function or member		5
First joint index finger right hand stiff	1	
First and third fingers right hand flexed and stiff	1	
Four fingers right hand slightly flexed and stiff	1	
Index finger left hand amputated	1	
Index finger right hand amputated	1	
Deaths . .		0

All of the cases in this group neglected prophylactic measures at the time of the minor injury, a few were given first aid by fellow employés, as attempted removal of a splinter from the hand, in which case a portion of it was left in, all reported to the doctor from three days to one month after receiving their injuries, and 7 were given office treatment by their family physicians for a few days before being sent to the hospital The 5 cases of permanent deformities, 2 with loss of fingers, are the direct result of the above negligence

CONCLUSIONS

In dealing with this question of hand infections, the student and the surgeon alike must recognize that he is dealing with a great economic problem and that much

depends on his ability to cope with it properly From the viewpoint of the infected individual, his future earning capacity is often at stake and this can be materially affected if poor functional results are obtained With more and more States enacting employés' compensation laws, industries, both large and small, are held responsible for employés' accidents and resulting complications Thus by the prevention and proper treatment of such a prevalent condition as hand infections, the surgeon—and especially the company surgeon—is able to save these industries a great financial loss The wise employer is beginning to recognize the retroactive results of the proper medical and surgical care of his employés, so that there is a growing demand for properly trained company surgeons

PART II.

Localized Infections and Clinical Entities Exclusive of Lymphangitis, Major Fascial-space and Tendon-sheath Infections.

CHAPTER X.

INFECTIONS OF THE DISTAL PHALANGES.

Felons, Paronychia.

FELONS

FELONS are among the most common infections of the distal phalanx The source may be a small pin prick or unnoticed injury, and occasionally no history of injury can be elicited The patient first notices a sticking pain in the distal phalanx, which rapidly becomes throbbing in character and most severe He cannot rest or sleep. The distal portion of the finger becomes red and swollen Early it is tender to the touch and this tenderness is most marked over the site of the infection In the later stages, after pus formation and tissue destruction, the sensitiveness disappears The phalanx is at first tense from the edema, more tense, in fact, than is ordinarily observed with edema, owing to the peculiar anatomical structure, which will be discussed later Soon the tenseness is replaced by an induration and later by a fluctuating, boggy mass

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The reason for the peculiar pathological condition which is present here in localized infection and nowhere else in the body is worthy of consideration The ordinary conception of the pathogenesis is that which has been attributed to Roux, whether justly or not I cannot say By this the lymphatic vessels are supposed to run perpendicularly from the skin to the periosteum, infection thus takes place under the periosteum, which is lifted off, and necrosis of the bone ensues Against this assumption we have the very firm attachment of the periosteum to the bone, Sharpey's fibers going down into the osseous tissue in such a way that it is practically impossible for the periosteum to be separated and differentiated as it is elsewhere Moreover, there are certain anatomical peculiarities which seem to point to another explanation of the necrotic process, so essentially different from that noted elsewhere in the body The connective-tissue framework is such as to produce a closed sac comprising the distal part of the phalanx, thus differing from the remainder of the finger, while the glands lying in the columns of fat present a portal for the entrance of pathogenic bacteria This will be seen by examining the accompanying cross and longitudinal sections of the phalanx Some of the glands may be seen lying near the periosteum Of especial interest is the presence of the bloodvessels which may be seen in the cross-section, one lying upon either side in the closed space and running parallel with the phalanx (Figs 54 and 55) Should pus or edema, the result of infection, develop to an undue degree in this closed space, it would have no means of free egress as in the other connective-tissue spaces Hence it would have a tendency to shut off the blood supply and cause necrosis of the bone. It will be seen by examining the longitudinal section that the portion of the bone involved is the diaphysis, since the epiphysis receives its blood supply before the vessels enter the closed space. Anatomically, then, we expect the

epiphysis to escape necrosis in these cases, and clinical observation corroborates this view, since the diaphysis is the part of the bone which is lost. This finds its most

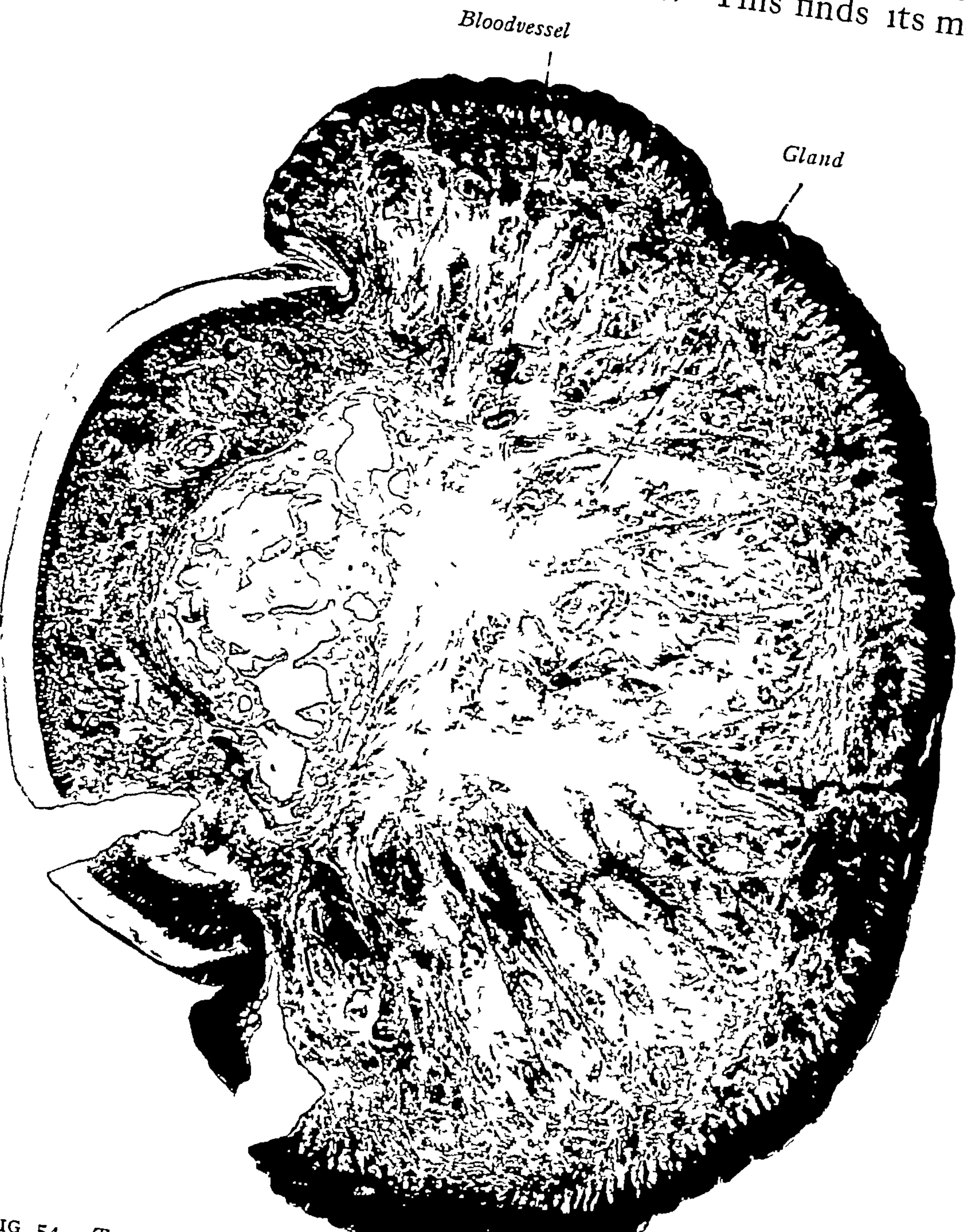


FIG 54 —Transverse section of distal phalanx, showing the closed pocket with columns of fat radiating from the bone The glands are well shown and demonstrate how easy it would be for pathogenic organisms to invade this space through these glands

perfect example in children and those whose epiphyses and diaphyses have not progressed to perfect bony

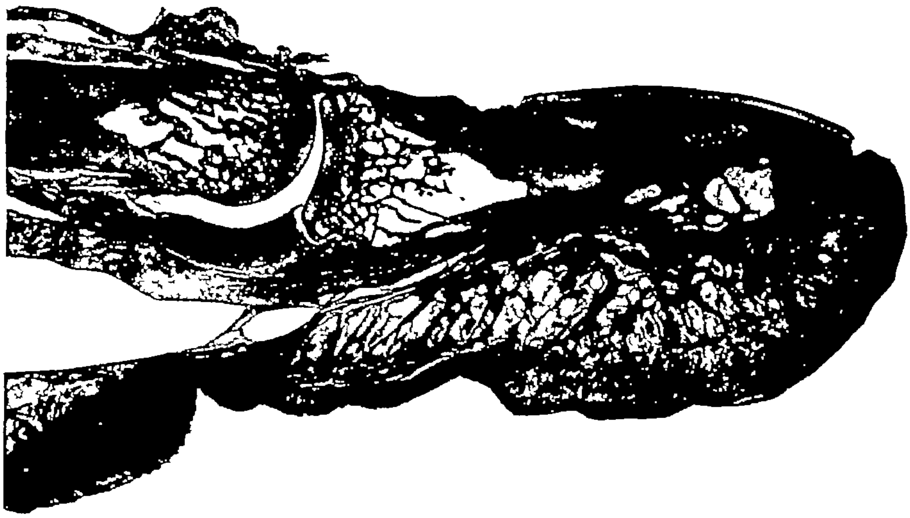


FIG 55 —Longitudinal section of the distal phalanx and articulation Note the closed pocket of the pulp of the finger and the columns of fat, with glands shown as dark dots spread throughout Note that the epiphysis is well separated from this pocket

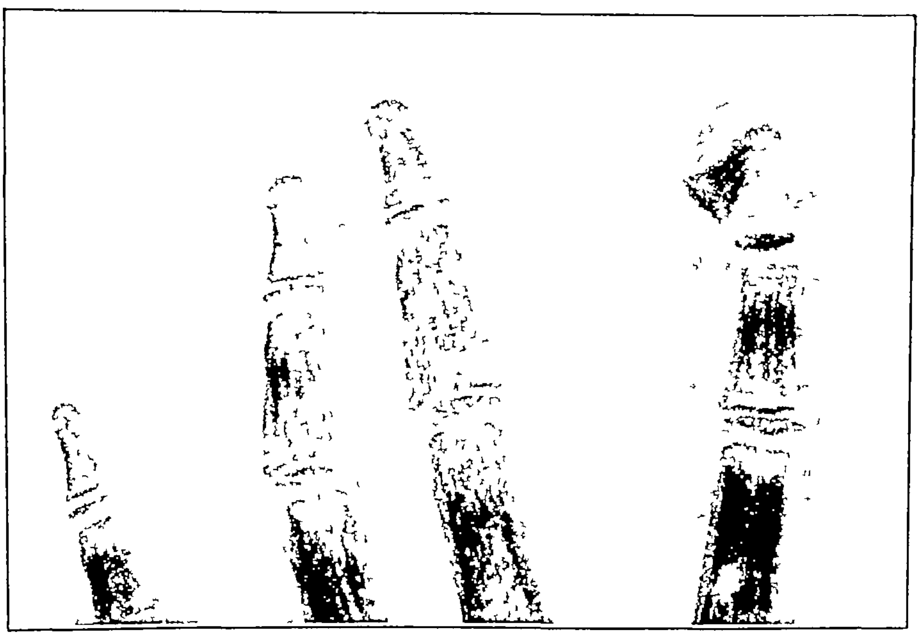


FIG 56 —V D, aged nine years Osteomyelitis of distal phalanx following felon Note separation of the epiphysis and diaphysis

union It has been my experience frequently to open these old felons in children and have the diaphysis fall

out of the sac, where it has been floating, a free body, in a sea of pus (Fig. 56) In adults, where osseous union has taken place, an examination will show the necrotic diaphysis standing out free from the surrounding tissue, with the epiphysis and joint, in the early stages at least, practically untouched by the destructive process

This explanation of the pathological sequence would seem to be more reasonable than that of Roux, and also explains the rapid recession of the process after an early opening, and the slow recovery when delay has permitted the disease to destroy the connective tissue which must ultimately be expelled as a slough

When the incision has been delayed or the process permitted to go on to spontaneous expulsion of the necrotic matter, we find a bluish insensitive pus bag with a sinus opening which frequently appears at one side near the nail As a rule, the granulation tissue is not excessive, the sinus appearing more as a simple canal uniting the pus pocket with the exterior. Fragments of seminecrotic connective tissue often appear partially plugging the opening

The diagnosis of a felon is made upon the redness, pain, tenderness and swelling of the pulp of the distal phalanx The pain is severe and the tenderness great. The end of the finger is bulbous, due to the inflammatory edema, and the swelling is more tense than that found in the ordinary simple inflammation

The felon is differentiated from lymphangitis and tendon sheath infections by the fact that in these there is symmetrical and equal swelling of the entire finger with the other characteristic symptoms of these infections.

TREATMENT —The treatment of felons consists in immediate incision into the infected area.

Certain errors in treatment are seen at times. The first is an incision made into a phalanx in which there is a beginning lymphangitis and not a localization in

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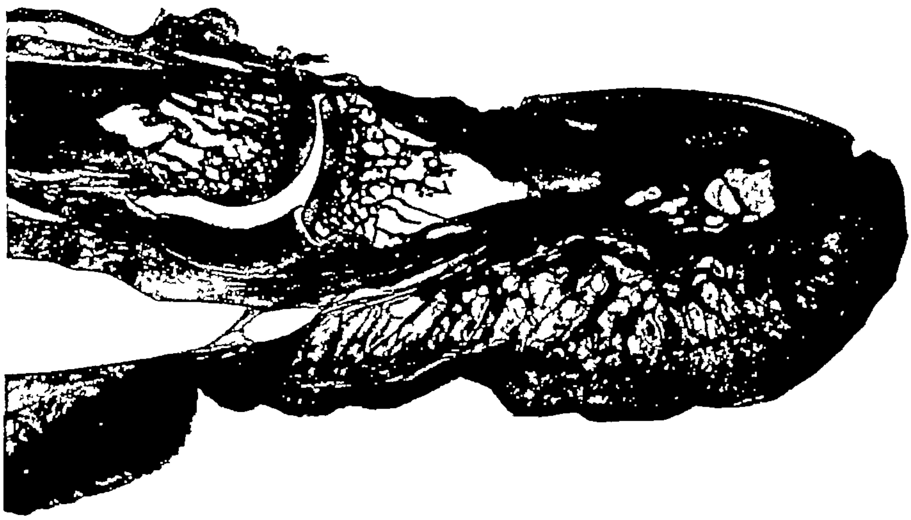


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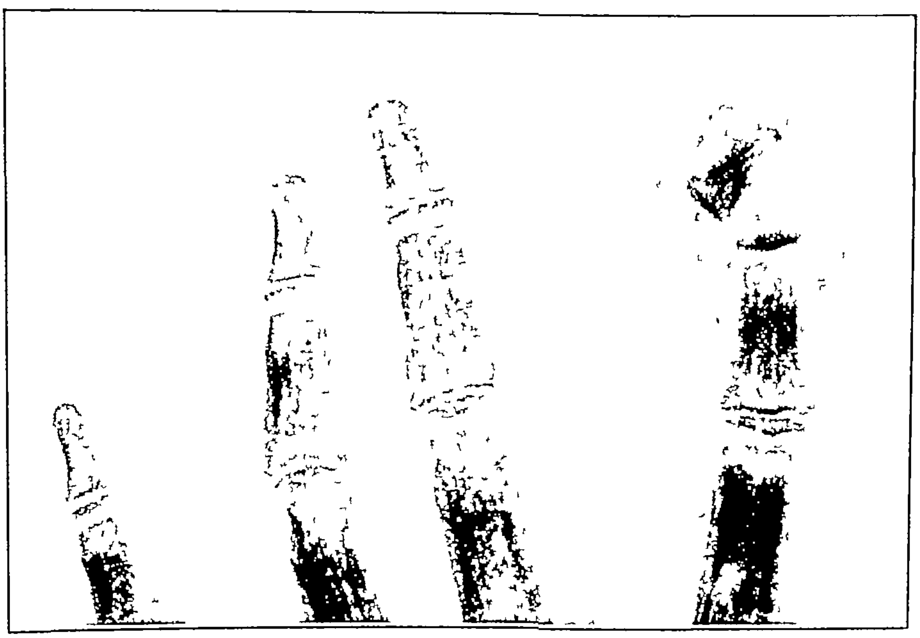


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The felon is differentiated from lymphangitis and tendon sheath infections by the fact that in these there is symmetrical and equal swelling of the entire finger with the other characteristic symptoms of these infections.

Treatment —The treatment of felons consists in immediate incision into the infected area

Certain errors in treatment are seen at times The first is an incision made into a phalanx in which there is a beginning lymphangitis and not a localization in

the distal phalanx Incision in such cases is not only unnecessary, but positively harmful, as will be brought out in discussing the subject of lymphangitis as a whole

The second error consists in waiting until fluctuation has begun If this is done, unnecessary pain is endured by the patient Moreover, such destruction of the connective tissue, and even of the bone, has occurred as to cause not only prolonged convalescence but also permanent deformity The incision should be made as soon as the edema restricted to the distal phalanx has proceeded to a degree causing a hardness, but not necessarily the board-like feeling characteristic of pus in other subcutaneous areas In general, one may say that when there is present a painful, tender distal phalanx, with excessive edema limited to the phalanx, incision should be made

Generally the patient comes for treatment after the whole area is involved, but at times the finger will be seen early enough to decide, because of the localized tenderness, that the pus has not extended throughout the whole of the closed space, in which case the incision should be made over the localized tender area In those cases in which there is no localization, but the whole phalanx seems involved, the incision should be made somewhat to the side, and not in the median line, as is unfortunately frequently done The median incision leaves a scar over the site of the tactile portion of the finger, so that the more delicate functions of that part may be impaired By examining the cross-sections here shown it will be seen that this pocket can be opened by a lateral incision just as satisfactorily as by a median one, and, in fact, somewhat better, since the radiating columns of fat and connective tissue will be cut transversely, thus leading to more satisfactory drainage (Fig 57) This incision should be long enough and deep enough to open the pocket freely The error is frequently made of being

content with a simple incision of the skin which evacuates the pus It should be remembered that seminecrotic connective tissue is present that will block a small opening If the incision is made early, one is often surprised at the rapidity of the recovery It has been recommended by some that the incision should extend in a circular direction around the end of the finger. While this gives perfect drainage it leaves a scar upon the end that inter-

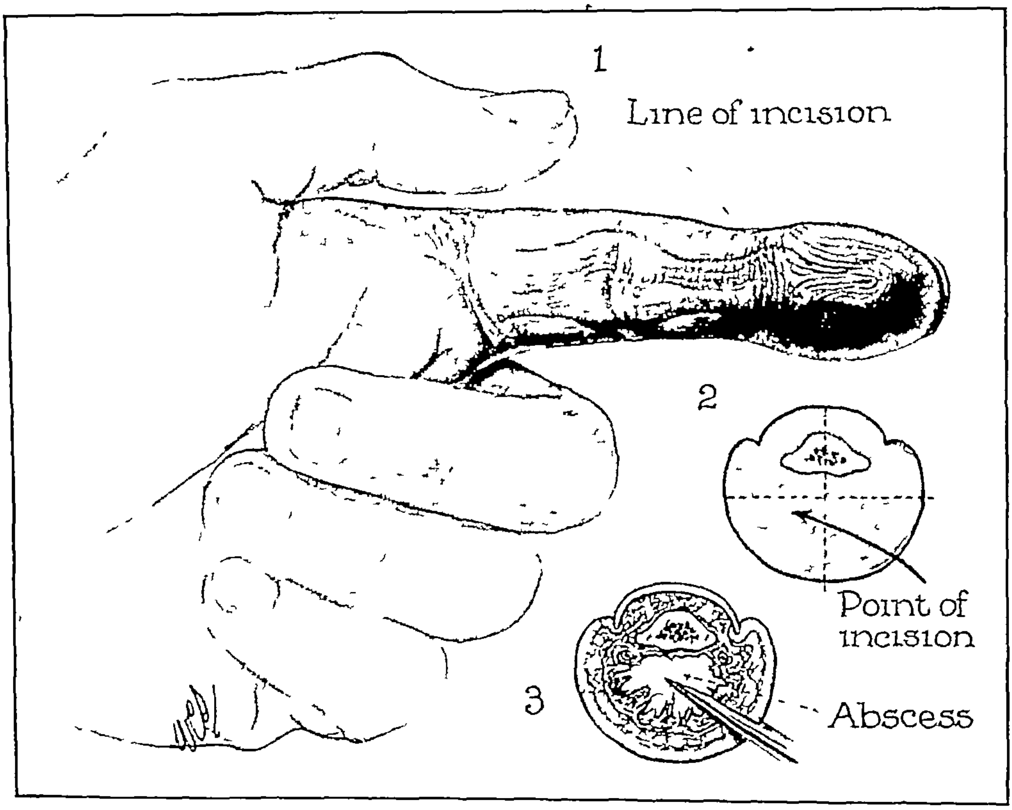


FIG 57 —Method of incision in felons (Koch, Jour Am Med Assn)

feres with function Attention should also be drawn to the fact that if a median flexor incision be made it should not extend beyond the base of the phalanx but rather fall short of it, since otherwise the development of a tenosynovitis is favored. I have met this unfortunate result several times in consultations

In those cases in which incision has been delayed until necrosis has ensued, certain phenomena may be observed.

The connective tissue of the pulp may be so destroyed that pus will continue to discharge until the slough of seminecrotic tissue is expelled. If the opening is small, recovery may be hastened by removing the detritus with tissue forceps. Its removal, however, must await the natural pathological process incident to all separation of necrotic from living tissue Its elimination is favored, however, by the instillation of Dakin's solution either through a small rubber tube left *in situ* for a short time or by frequent injections through a pipette

Again, when the bone is involved the question often arises as to what disposition to make of it This will vary with the amount of involvement If there is complete separation of the tissues from the diaphysis, so that it stands out free like a telegraph pole in the pus, it should be removed at once by the bone-cutting forceps, remembering that the epiphysis is not involved In the case of a child the diaphysis is often separated at the time of incision or can be easily cut off with the scissors because of the lack of bony union between the epiphysis and diaphysis If the bone is exposed upon only part of its circumference it will frequently heal without further trouble and should be treated conservatively In those cases in which the diaphysis is removed no disability of the joint need be feared unless it has become involved, a complication occurring only in a few instances The phalanx will be somewhat short and the finger nail may be deformed, but movement will not be seriously impaired If the necrotic diaphysis is removed *in toto*, or in part, a rapid regrowth of bone ensues (Figs 58 and 59) A more symmetrical distal phalanx may be secured in these cases by the constant wearing of a shaped aluminum ring or even adhesive plaster during the regrowth of the bone

If the joint should be seriously involved with much destruction of bone, amputation is generally advisable. The after-treatment is the same as that used after any

incision in acutely infected areas, consisting essentially in procedures designed to relieve pain and favor walling-off of the process by round-celled infiltration. Locally nothing is superior to the ordinary dressing saturated with hot boric acid solution until the acuteness of the inflam-



FIG 58 —Osteomyelitis of distal phalanx The first roentgenogram shows osteomyelitis, the second was taken two days after removal of diaphysis, the third, fourth and fifth show the various stages of repair over a period of six months The patient has complete function in the joint

mation subsides The hand is elevated to lessen the throbbing pain. These measures are supplemented by opiates if necessary After the acute inflammation subsides the finger is dressed by gauze thoroughly saturated

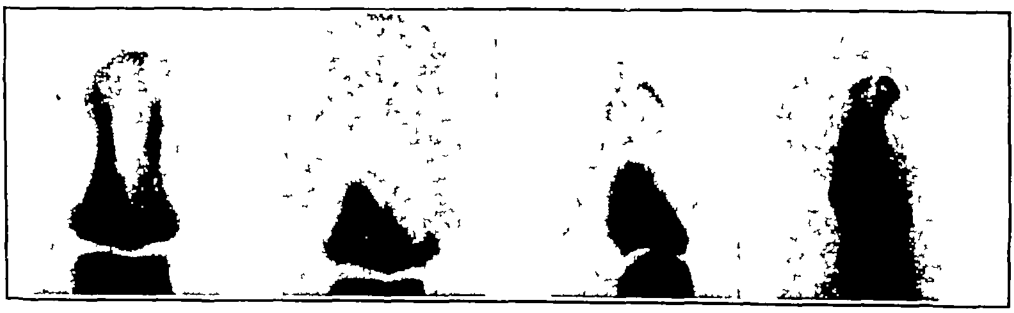


FIG 59 —Osteomyelitis following accidental vaccination injury with subsequent infection The first roentgenogram shows osteomyelitis, the second was taken immediately after the removal of the diaphysis, the third and fourth pictures were taken during the course of eight months and show complete repair of the diaphysis The patient has complete function in the joint

with vaseline, which permits the free escape of pus and permits the removal of the dressings without pain to the patient

When the resulting scar impairs the function of the

finger some benefit may be secured by operation. The accompanying photographs of such a finger demonstrate the result after the obliteration of the contracted scar by the transplantation of a free pad of fat from the abdomen to the distal phalanx The patient was a harpist and, as will be seen, the contracted scar prevented the patient from grasping the string by the thumb An incision was made upon the opposite side of the distal phalanx, the constricting scar tissue cut and the skin elevated Into the space the free transplant of fat was placed and the wound closed This completely obliter-

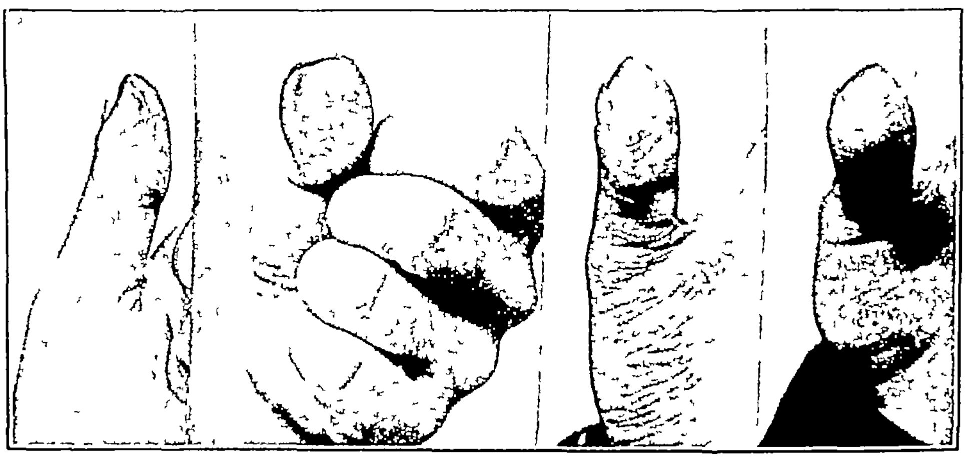


FIG 60 —The first two photographs show the scar contraction of the distal phalanx, and the last two the appearance of the finger after the transplant of fat

ated the depression and permitted satisfactory use of the thumb in playing It should be remembered in this connection that some of the fat will be absorbed, consequently the finger should be overdistended (Fig. 60).

PARONYCHIA

Among the infections of the distal phalanx, none is apparently so simple as the paronychia, or "run-arounds," and yet they frequently baffle treatment for some weeks, since the pathology may not be understood. They begin

ordinarily at one side of the nail as a simple infection, frequently from a "hangnail" Not infrequently they follow manicuring with septic instruments In these cases they may be multiple. I have seen infections in different individuals received from the same manicure parlor.

This infection may be of two types: first, an acute infection, giving rise to a small wheat-grain-sized abscess in the subepithelial tissue at the side of the nail, which, if opened, makes an immediate recovery; if neglected, it spreads along the side of the nail and back to the base, becoming secondarily a typical "run-around." More often, however, a sluggish type develops from a chronic infection along the edge of a "hangnail." For a number of days a drop of pus or more will exude from the inflamed area about the nail edge It will then be noticed that on the same side at the base there is a certain amount of swelling and redness, with little or no pain. As the days pass the swelling and redness gradually extend about the base of the nail until the opposite side is reached At the end of two or three weeks drops of pus will be expressed from under various parts of the overlying epithelium (eponychium). A week or two later the entire nail may be lifted off the matrix and cast off, or at least detached along its entire base. Meanwhile, a chronic discharge of pus continues from the original nail sulcus from under the eponychium, since the swelling and edema do not favor satisfactory drainage. This continues for some time, during which the matrix begins to proliferate freely and an almost fungus-like elevation of granulation tissue appears, growing from underneath the overhanging cuticle. This picture of the neglected case is not at all uncommon, owing to the habit of the patients to consider this infection as unimportant and consequently to treat it by poultices and salves In this they are often abetted by the ill-informed physician. At times, it is true, spontaneous

recovery may take place, but most often the nail is lost after a more or less prolonged course.

Let us consider the pathology of these chronic inflammations when they spread to the base of the nail. It will almost always be found that the pus is under the overhanging edge of the nail. Upon extension the pus follows around the nail sulcus, still under the nail The soft and delicate nail root, under the eponychium, is raised entirely off of the nail bed, although the distal exposed portion of the nail is still firmly attached to the matrix

Treatment —With a clear understanding of the above pathology, it is manifest that the only proper procedure is to allow escape of the imprisoned pus In the earlier stages one may, with a blunt knife edge, press back the overlapping eponychium so as to permit the escape of the drop of pus Tincture of iodine is then applied Recovery generally follows promptly If such prompt treatment is neglected and a larger area is involved, it is necessary to make a longitudinal incision along the outer edge of the nail, going back to the base as far as the sulcus, with especial care, let me emphasize, to cut to the outer side of the nail so as not to cut the nail bed or the overhanging cuticle, since if this is done it may result in a permanently split nail when it grows out anew The eponychium is now pushed back with a sponge and the point of a sharp scissors inserted under the detached edge of the nail and this is cut off, together with as much of the root of the nail as has become separated from the matrix by the pus It is wise, generally, to be on the side of radicalism, since otherwise secondary operations may become necessary After removing this portion of the nail the elevated flap of overhanging cuticle is packed up and out of the field by a small strip of gauze saturated with vaseline to favor drainage for a few days A hot moist dressing is applied to the entire finger for a couple of days, after which time a vaseline gauze dressing or dry

dressing is applied as the case may demand. The dry dressing should not be too voluminous. It is well to make the dressing as light as possible so that the wound will dry up. It is wise to remove the dressing for several

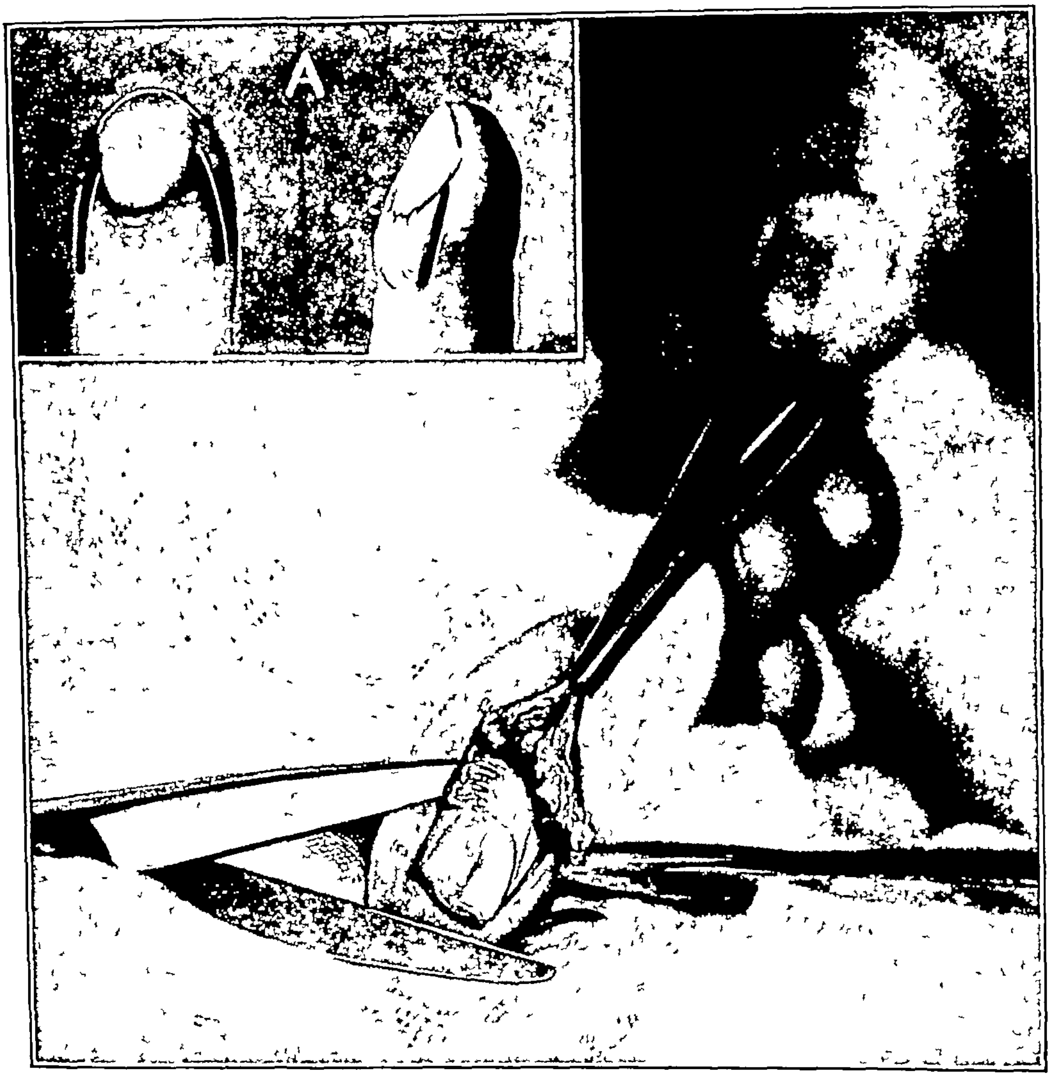


FIG 61 —Photograph of steps of operation for paronychia (*A*) Incisions Flap has been raised and the point of the scissors inserted under the base of the nail

hours each day and expose the finger to the drying rays of an electric light

Concerning those cases in which more than half of the base has become involved in the swelling and redness, a word further is required Here a second incision should

be made upon the other side of the nail, using the same precaution as in the first incision, not to cut the nail bed or the overhanging cuticle (Fig 61) The eponychium which is now entirely separated from the epithelium on its two sides is pressed back and elevated as before, exposing the entire sulcus The loosened portion of the nail in these cases will often comprise the entire nail root This is completely removed, leaving the distal portion of the nail still attached to the matrix. Gauze is packed in, as before, to raise the flap and secure drainage (Fig 61)

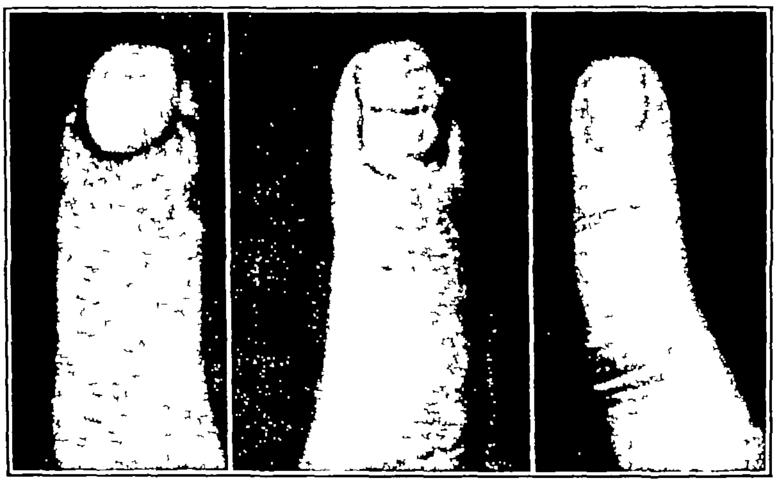


FIG 62 —Paronychia with removal of the base of the nail and complete recovery and repair in seven weeks

It is not necessary to remove the distal portion if it is not already detached It does not interfere at all with recovery, and is still of some service after the acute inflammation at the base subsides The new nail rapidly forms, and in growing out pushes the old nail in front of it (Fig 62)

In those cases in which the condition has been neglected or in which the liberating incisions have not been made at the sides, a considerable cauliflower-like growth of granulations may appear, as has already been mentioned This is, of course, due to the irritation incident to inadequate drainage Hence we should see that the drainage

is free This will be followed by the formation of nail and the rapid disappearance of the granulations I have never yet cauterized these In one intractable case rapid relief was secured by placing a rubber band about the base of the finger, producing a Bier's hyperemia for some days.

Occupational Paronychia —Workers in certain industries are liable to chronic chemical and bacteriological involvement of the nail or its bed For instance, confectioners, who handle fermenting fruits and spray them with sugar, cooks, bartenders and others dealing with fermenting grain and vegetables often have chronic processes about the nail The nail loses its luster, turns dark, becomes flat and is finally separated from its nail-bed and lost with persisting chronic inflammation of the nail-bed Laundresses also through chemical and mechanical injury may suffer from partial or completely onycholysis Generally the involvement of the nails is multiple.

The treatment of these cases consists in either abandoning the occupation or protecting the hands by rubber gloves Varying with the degree of injury the immediate care calls for bland ointments, partial or complete removal of the nail

CHAPTER XI

CUTANEOUS AND SUBCUTANEOUS INFECTIONS.

Carbuncles, Subepithelial Abscesses, Erysipeloid, Indelible Pencil Injuries, Acute and Chronic Infections, Blastomycosis, Etc.

CARBUNCLES

THE carbuncles which develop on the hand are typical of that condition elsewhere Carbuncles, although seen frequently, are often not understood by the practitioner who therefore does not take the proper steps necessary to their immediate cure

They may develop in any portion of the dorsum containing hair follicles, their most common site, therefore, being the dorsum of the proximal phalanges (Figs 69 and 70) and the back of the hand upon the ulnar side The various types of staphylococci are most often the exciting organisms The peculiar pathology characteristic of this condition is due to the nature of the skin and the subcutaneous tissue with its sweat glands, hair follicles, and columns of fat extending up into the derma

Anatomical Considerations and Pathogenesis — In an attempt to determine the source of these infections and the cause of their persistence, I made serial sections of a portion of the skin and identified the various structures in the succeeding sections, without, however, being able to say definitely that the source could be attributed to either the sweat glands or hair follicles alone Repeatedly on examination a hair follicle with its sebaceous gland could be found in the subjacent columnæ adiposæ,

on the other hand, it almost as frequently occurred that the convoluted sweat gland would also be found (Figs. 63 and 64). One could only conclude, therefore, that it was possible for the carbuncle to begin from either, although it seemed more reasonable to attribute its source to the hair and its sebaceous gland Garré, Budinger, and

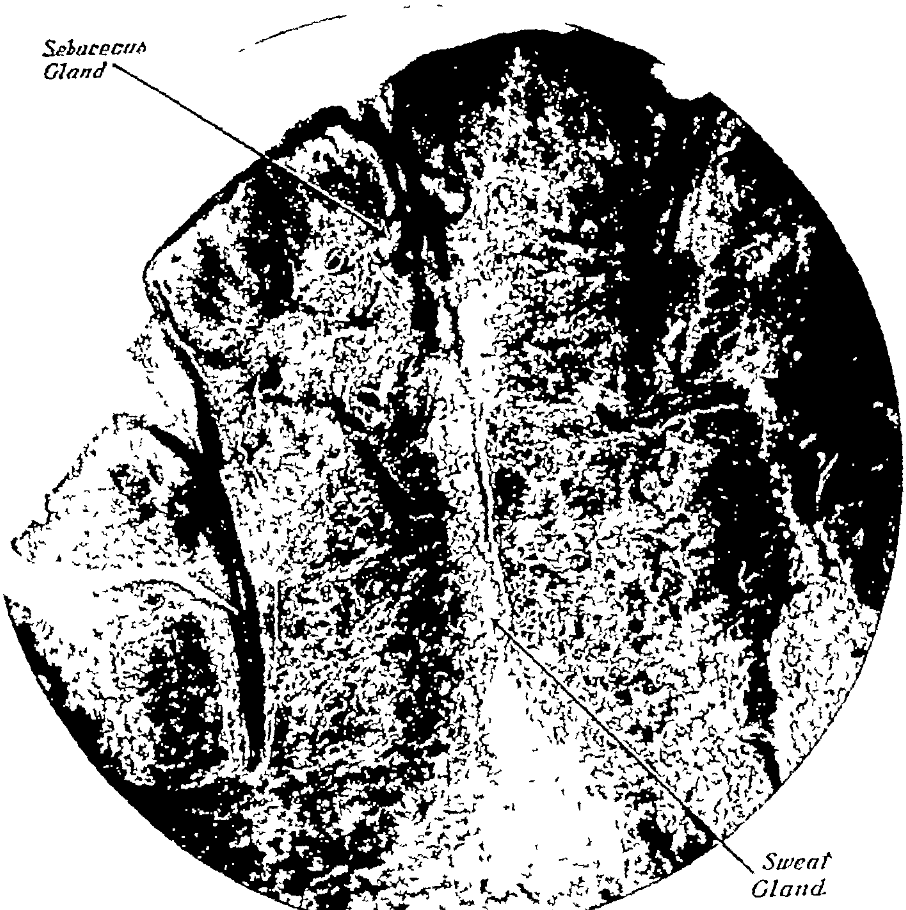


FIG 63 —Sagittal section of the skin, showing columna adiposa At the upper part note the hair follicle with its sebaceous glands connecting this column of fat with the skin. In the lower portion of the column of fat a sweat gland is seen

others have demonstrated upon themselves that it is very easy to produce such infections by rubbing into the skin virulent streptococcus cultures

In the accompanying microscopic illustration of a cross-section of the skin, the various columnæ adiposæ may be seen with the hair follicles, sebaceous glands,

and sweat glands in various locations (Fig 63). From a study of this, the course an infection will pursue can be seen readily. Beginning in one of the columnæ, the accumulation finds readier escape downward into the subjacent fat From there it spreads laterally and gradually fills the loose mesh under the skin and ascends into the various columnæ, from whence the infection extends to the surface from these many sources, straining

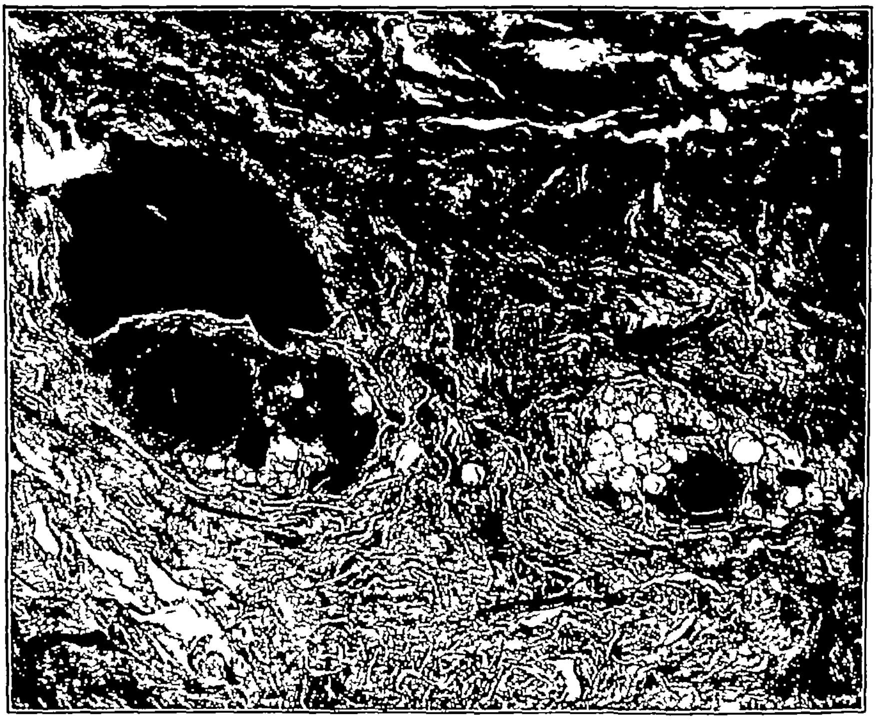


FIG 64 —Section parallel to the skin Note that here we have two columnæ adiposæ cut transversely In one a hair is seen and in the other a hair and a sweat gland It is readily seen how pus would follow along these to the surface

through a sieve, as it were. As the process persists the central part of the surface becomes necrotic, and through this is extruded pus and seminecrotic connective tissue Even this does not give free drainage, and the process still tends to extend around the periphery Meanwhile, more and more of the overhanging skin becomes destroyed, until such time as enough surface is destroyed to give free exit to the pus and the surrounding inflammatory infil-

tration walls off the infection, which it does with difficulty owing to the many interstices in the loose mesh of subcutaneous tissue through which the pus can extend. An examination of a schematic cross-section of such an inflamed area shows these various facts. Clinically they are observed on the surface as follows: First, the central necrotic area, about this the area of tissue shows punctate pus exudations, and beyond this a bluish circumference through which the pus has not penetrated, although it is under the skin, and, finally, surrounding it all, an area of induration denoting inflammatory reaction

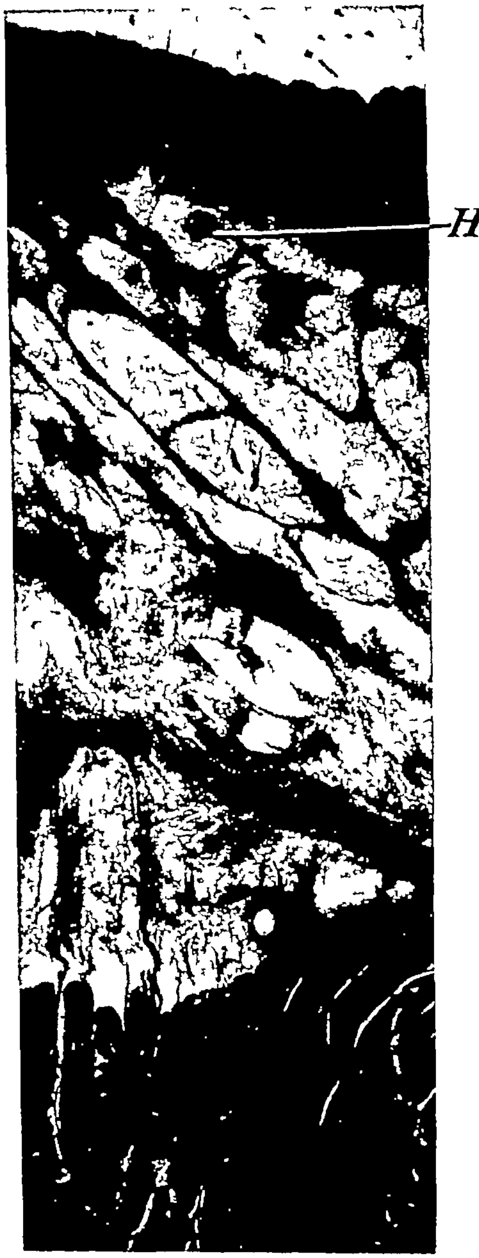


FIG 65 —A section of the skin, subcutaneous tissue, and muscle, showing the area in which the pus of a carbuncle develops and how it spreads beneath the skin and comes to the surface through the various dark lines in the skin which represent the hair follicles Note several dark dots (*H*) in the fat underneath the skin These are cross-sections of hairs which have penetrated beneath the skin and lie in the fat

TREATMENT —These cases are best treated by a crucial incision, the ends of which extend beyond the edge of infiltration, followed by incisions under the skin, so that this may be raised off of the underlying tissue (Figs 66 and 67) The base of the flaps should correspond with the end of the crucial incisions Hot, moist gauze is now packed under the flaps to insure drainage The patients are always anesthetized, nitrous oxide being preferable The reasons for carrying the incisions in the

skin beyond the edge of inflammatory exudation, as indicated by the induration, are difficult to understand The principle is directly opposed to the ordinary conception of this area as a protecting wall, which in other conditions we would use every possible precaution to

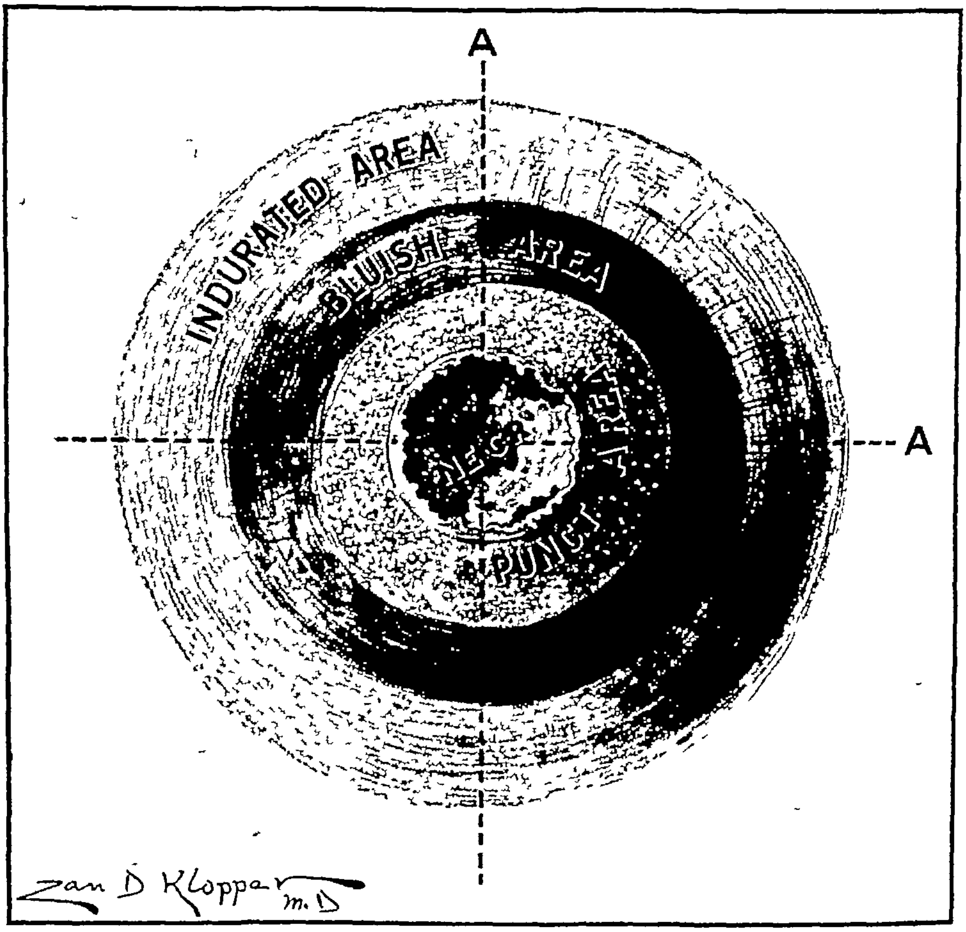


FIG 66 —Schematic drawing, showing the areas of the carbuncle with the length of incisions upon the skin (A, A)

preserve Of the advisability of the length, however, I have no doubt, since I have had occasion to use this method in a large number of cases, and whenever the technique described has been faithfully carried out the result has always been satisfactory If, however, through a conservatism I fell short, the extension always took

place along that area, while the sides where I had made the long incisions would go on to satisfactory recovery. This same holds true for carbuncles of the neck and other areas.

The cuts parallel to the skin designed to free the skin from the deep fascia should be made about midway

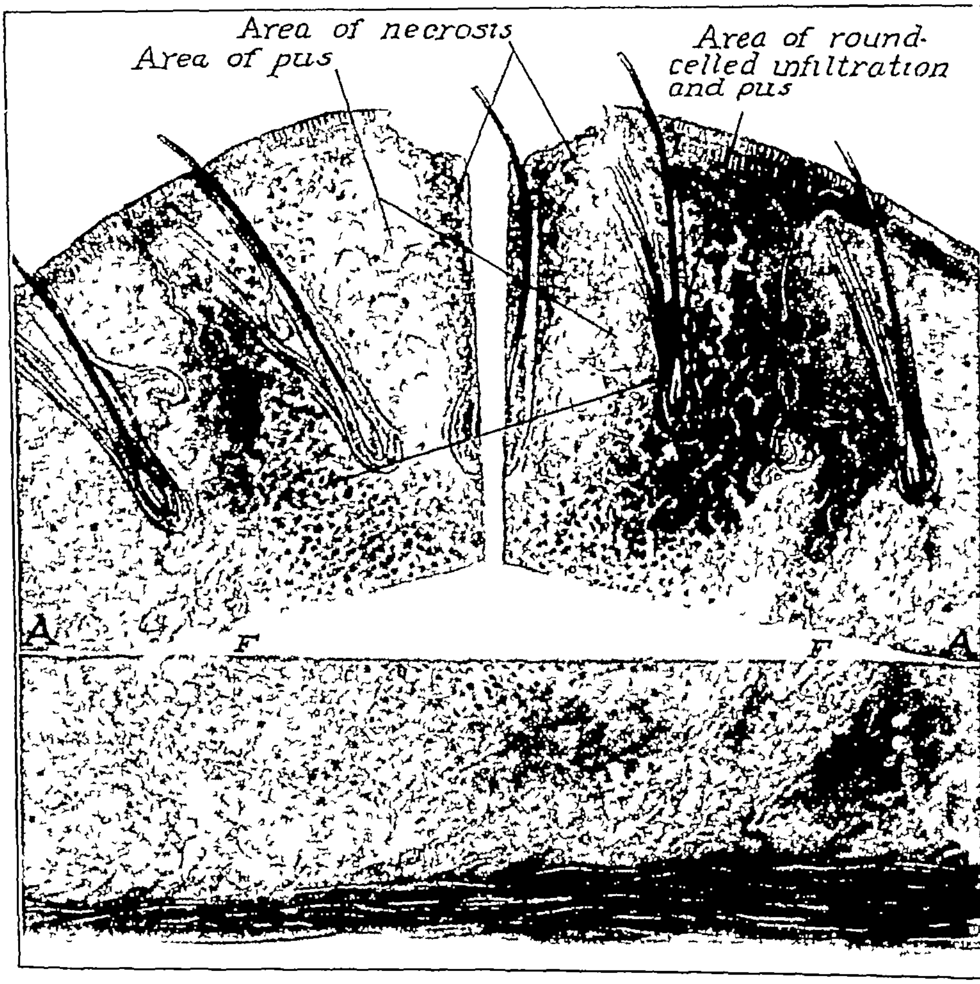


FIG 67 —Schematic drawing, showing areas of infection in the carbuncle and the method by which, through a transverse incision parallel to the skin, the flaps are raised up Note that this incision *F* goes beyond the limit of the area of round-celled infiltration

between these two layers, going back through the area of induration also (Fig 67) Any arterial bleeding is stopped, but the venous oozing is controlled by packing, and this packing should be sufficient to raise the flaps well up The packing is removed at the end of twenty-

four hours, and the flaps allowed to fall back If there is not much venous oozing, the gauze is thoroughly saturated with vaseline, which allows drainage and permits removal without pain to the patient

If there is any free slough it is removed at the time of operation It is not necessary to curette or cut away

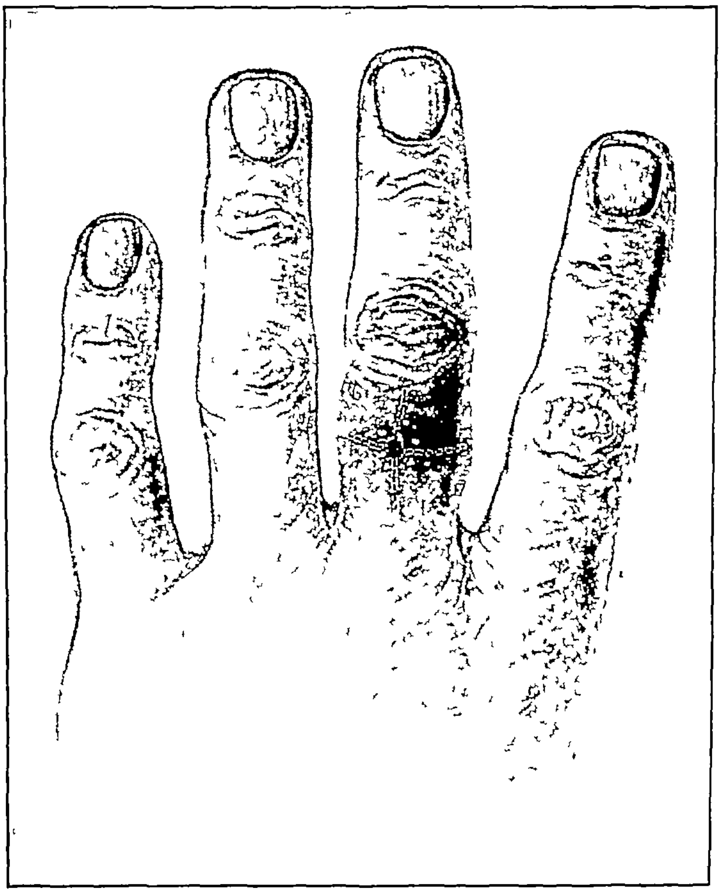


FIG 68 —Incision for carbuncle on the dorsum of the proximal phalanx Note that the incisions extend beyond the area of induration

any tissue whatever Dakin's solution applied after the approved method hastens the removal of this necrotic tissue The removal of any of the skin, no matter how much damaged and fragmentary, should be condemned, since one is always surprised at the rejuvenation of apparently hopelessly injured skin After repair has begun I have often found the flaps to fall into place and

leave a granulating area no larger than a dime, where it had seemed the entire area must be lost. For that reason also one should condemn most severely the procedure advocated by some of excising the entire area. On the other hand, the crucial incision without undercutting and raising the flaps is futile in a majority of cases, leading to repeated operations and prolonged convalescence

CASE I —In this connection the history of a patient sent to me for treatment is interesting When first seen he had been suffering for three weeks with a carbuncle on the dorsum of the left hand It had begun as a small pimple on the ulnar side, and incisions had been made on six different occasions at different points The infection had spread to involve the entire dorsum, and had extended to the flexor surface around the thumb and the wrist at the ulnar side. The sloughing connective tissue was being extruded from the incisions and small necrotic ostia which had appeared over its surface In other places it had the characteristic appearance of a carbuncle.

The patient was anesthetized and a crucial incision made, not, however, carrying the incision the full length of the infected area, for fear of impairing the nutrition of the flaps The entire area, however, was undermined and gauze saturated with hot boric acid solution carried to the edge An immediate cessation of the process took place except at the wrist, where a subsequent incision had to be made, owing to the inadequacy of the early incision When the flaps finally healed, it was found that no grafting was necessary So much of the skin had retained its vitality that the denuded areas were soon covered by epithelium

At times I have been compelled to cover a small denudation by a Thiersch graft from the patient's body. This should be done as soon as a good granulating base has been assured This, in my experience, is more often necessary on the dorsum of the finger than on the back of the hand

The illustrations show, in both cases, beginning carbuncles (Figs 69 and 70) The one on the finger had been treated a week before it came under my observation, and, after incision, was dressed only twice and was entirely well in a week. The one on the dorsum of the hand had

been treated for six days after a simple incision After opening it properly and applying the Bier suction cup,

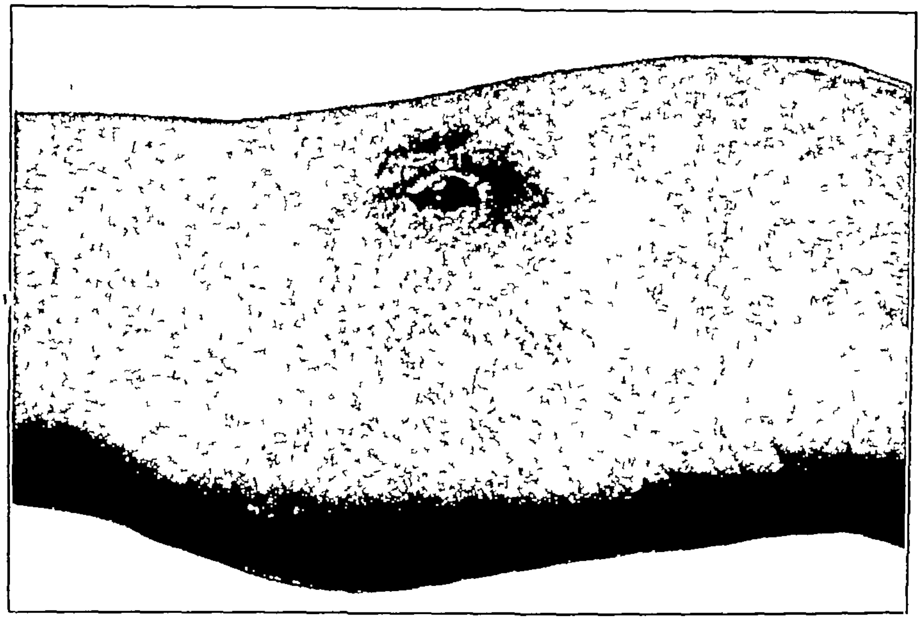


FIG 69 —Beginning carbuncle on the ulnar side of the dorsum of the hand

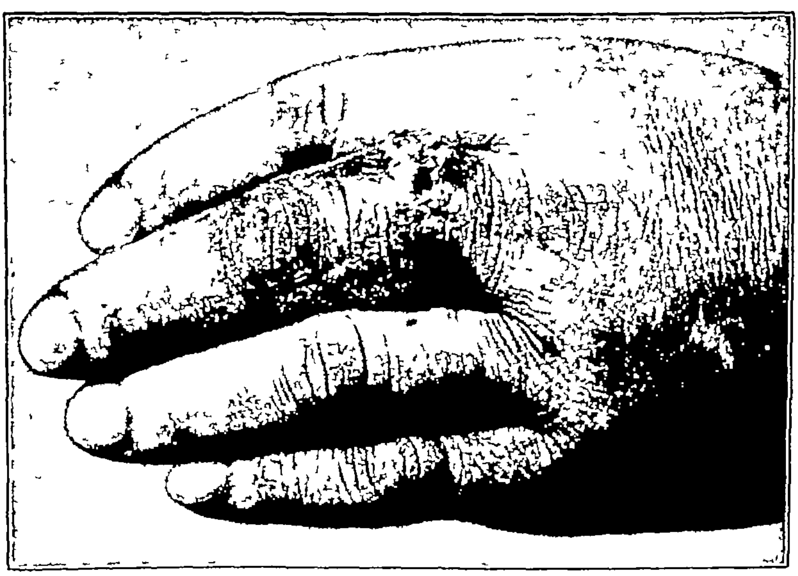


FIG 70 —Carbuncle on the dorsum of the proximal phalanx.

which I have at times used with success, entire healing followed in a week. This picture of an apparently simple

case is presented, since it is in such that the diagnosis is not made They are considered simple abscesses The more severe cases with the punctate areas of pus, if they are acute, are recognized by all.

SUBEPITHELIAL ABSCESSES

It is not at all uncommon for subepithelial infections to take place either as local processes or associated with more extensive infections. The epithelium may be raised over a considerable area, both upon the flexor and the extensor surfaces This kind of infection is frequently seen as a local process about the distal phalanx, the contents being generally a seropurulent fluid of a low grade of virulency

The treatment consists in removing the elevated epithelial covering and applying some dry dressing or hot boric dressing as the virulency of the case demands. It is essential that every part of the detached epithelium be removed, otherwise the moist, warm pocket will favor the further development of the infection

ERYSIPELOID

Erysipeloid is a descriptive name introduced by Rosenbach to describe a clinical picture known to older writers as erythema migrans or chronic erysipelas. It is now established that the etiological factor is the bacillus of swine erysipelas. The organism appears either in pathogenic or saprophytic form throughout the animal kingdom Any animal may transmit the infection to man, the most common sources, however, being fish and crabs with swine holding a second place It is therefore seen most often in fishermen and employés in canning factories.

The organism finds entrance through some minor injury and the symptoms develop ordinarily in about three days The clinical pictures may vary. The commonest

type presents a local process without systemic symptoms, but at times we see lymphangitis with glandular swelling or even with severe systemic reactions In other instances the course may be chronic with exacerbations and complicated with endocarditis or other systemic foci All of these types except the simple local form are exceptional, particularly in the United States

The inflammation begins with itching and burning at the site of the injury followed by a bluish-red coloring and moderate edema of the skin, rather sharply circumscribed This spreads slowly to the base of the finger where it pauses and then may extend to other fingers or the back of the hand It is exceptional to see an extension to the back of the forearm or the palm The surface of the area may show bluish or brownish-red urticarial blisters or blebs There is generally no fever or other systemic symptoms Locally the inflammatory reaction extends into the deeper tissues of the finger After several days to three to four weeks the process disappears, but may recur if the part is traumatized

The infection is self-limited and local treatment is of little avail except to allay the itching and burning Hot dressings, tincture of iodine, and other local applications are often used, but probably are not of great therapeutic value It has seemed to us that hot boric acid solution on dressings was the most rational procedure

In serious or complicated cases the injection of swine erysipelas serum is indicated and, indeed, if it is readily available, its use in simple cases will shorten the course In these simple cases, however, the suffering from a possible serum sickness will often outweigh the discomfort from the lesion The serum may be given intramuscularly or even intravenously in severe types Its administration subcutaneously around the lesion in the ordinary case is entirely satisfactory The dose given must vary with the serum used. In simple cases one injection

may suffice, but it may be repeated if necessary In repeated injections the surgeon must guard against sensitization

INDELIBLE PENCIL INJURIES

Injuries from the accidental insertion of indelible pencil points present a peculiar and rather typical clinical picture They require treatment essentially different from the ordinary injuries

The history obtained is generally that the patient accidentally thrust the point of an indelible pencil into the tissue and broke off the point The degree of reaction is dependent upon the chemical nature of the pencil, its density, and whether or not it was fragmented at the time of the injury Erdheim, who first drew our attention to the injury, made experiments in which he showed that the aniline dyes increased in their degree of toxicity from those that were green, through yellow, red, brown up to the very toxic blue It is thought that the methyl violet is more liable to produce only local reactions, while the methyl blue will show more systemic reaction The necrosis is supposed to be due to the union of the alkali with the acid nucleus of the cells

The dye dissolves in the organic fluid and diffuses rapidly locally and the necrobiotic processes keep step with the progressive infiltration of the coloring matter In the ordinary case in from twenty-four hours to a week, varying with the toxicity, a pathological section of the injured area will show a central area of necrosis filled with semiliquid fluid stained the color of the dye, around this will be found less stained tissue walled off from the normal tissue by round-cell infiltration, all forming a pseudocyst In the less toxic cases only stained granulation tissue may be seen In the more toxic a greater destruction is found with osteoporosis of the bone if it is involved Very exceptionally there may be sys-

temic absorption In experiments upon small animals, renal, hepatic, and pulmonary alterations with a fatal issue have been found Because the pencil point dissolves slowly the necrosis may continue for weeks or months Unless contaminated the necrotic fluid contains no bacteria.

Varying with the rapidity of absorption and the chemical factors noted, the clinical course may show a slowly forming granulating tumor, a chronic discharging sinus, or a rapidly forming open necrotic sore Exceptionally systemic reactions are present, consisting of headache, malaise, and a slight rise in temperature In the ordinary case no attention is paid to the injury for one or two days, when the patient begins to complain of local pain both spontaneously and upon pressure There is evident local inflammation about a dark violet, central discoloration. Sometimes there is a feeling of weight in the arm but the glands are not swollen The amount of pain and its persistence vary with the degree of irritation or necrosis of the nerves If untreated a spontaneous opening occurs with the discharge of dye-stained serum and necrotic tissue After some days or weeks healing takes place, but not infrequently there is a recurrence of the local process after some weeks or months This history is repeated until all of the dye is spontaneously expelled The same course follows simple surgical opening of the necrotic cyst In this case, if ill-advised attempts are made to remove the pencil point by forceps, there may be an exacerbation of the local reaction due to the crushing of the pencil point and the consequent rapid absorption of its toxic elements.

At other times little reaction is seen for six, ten to forty days, when generally less violent but more persistent symptoms develop In these cases spontaneous opening may not occur There remains, however, a tender tumefaction with the periodic recrudescence of

symptoms for weeks or months. Again the local area may heal and other adjacent areas may be involved from diffusion of the dye Exceptionally the systemic symptoms may be severe, but no fatal case has been reported In Germany where the largest number of cases have been observed, the use of such pencils is prohibited in the public schools because of the disastrous results to the eye from the accidental puncture of the conjunctiva.

TREATMENT.—In every instance there should be a complete excision of the entire area involved. All tissue colored by the dye as well as the pencil point should be removed If done promptly the wound may be sutured, if late it is frequently wise to drain the wound While recovery may take place after simple incision and drainage the probability of recurrence is great. Attempts to remove the pencil point by the forceps after puncture are ill-advised, since the crushing of the pencil point spreads the dye and causes a greater necrosis

If extensive necrosis has occurred a wide excision may be necessary with a curettement of involved bone. At times the destruction has been so great as to necessitate partial amputation of a digit

We have observed 3 cases, 2 shortly after the injury and 1 referred to us three weeks after the injury In all of these an excision was done with complete and permanent recovery

The medico-legal aspects should not be forgotten by the physician It is generally an occupational injury, commonly imposing liability upon the employer, and if not adequately treated may entail long-continued disability.

CHRONIC CUTANEOUS AND SUBCUTANEOUS INFECTIONS

Not infrequently we see upon the hands and arms low-grade cutaneous and subcutaneous infective proc-

esses or ulcers that have been treated for some time by ordinary methods without avail They have commonly not received from the attending surgeon the attention they should have since they have begun as mild infections

In many instances the difficulty arises through the triviality of the injury itself since this engenders inattention and neglect In other cases through carelessness there is violation of the fundamental principles of surgery and in another group improper treatment is instituted due to lack of knowledge of the pathology and clinical course of certain specific lesions

It may be stated as an axiom that all trivial injuries, if properly treated, should end in prompt recovery, and when this does not occur the surgeon should not be lulled into a sense of false security, but should at once institute an investigation as to the cause of the delay in healing A search should be made for sugar both in the urine and blood, for nephritis, lues, improper hygienic conditions and such general factors It should be ascertained if, in the course of treatment, harmful applications have been made, such as carbolic acid, bichloride of mercury or other irritating medicaments, if, through dressing, reinfection has taken place, or if because of continued movement due to inadequate fixation the lesion is not permitted to heal It should be remembered that in bite infections the wounds may be infected with organisms peculiar to the mouth, with consequent foul-smelling or gangrenous processes These wounds demand exceptional primary cleansing, with wide opening of the wounds Finally, careful thought should be given to the possibility of the infection being primary luetic infection or due to some other unusual organism

LOCALIZED CHRONIC INFECTIONS —Localized chronic staphylococcic ulcers are not uncommonly seen, generally upon the dorsum of the hand They may extend to cover a large area, some parts showing pinkish, glis-

tening new epidermis, while others show an active process appearing as an ulcerating granulating surface, more often slightly depressed A pure culture of the staphylococcus is found In the cases I have seen upon the dorsum of the hand, it is believed the process has its origin in the peculiar anatomy of the dorsal skin I have described in the consideration of carbuncles, superinduced by a lowered resistance and possibly by the irritation of various treatments applied

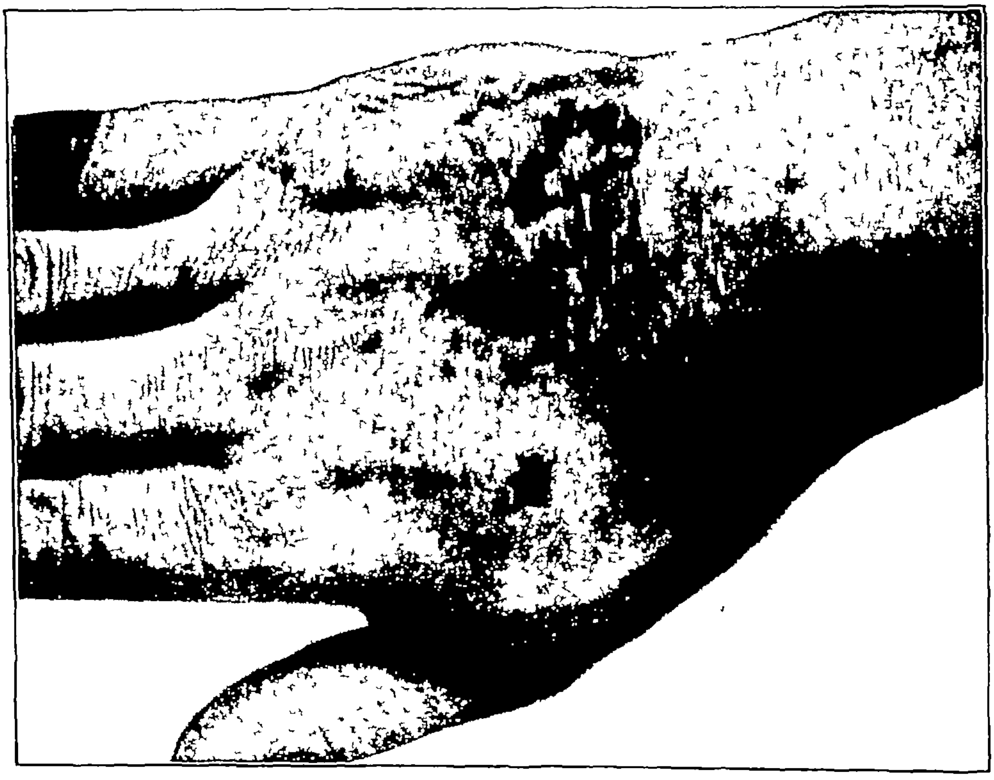


FIG 71 —Chronic staphylococcus infection of the dorsum simulating oidiomycosis

These lesions generally heal under bland applications, exposure to sunlight or ultra-violet rays for short periods daily, and fixation to produce rest of the part An autogenous vaccine may be of value.

NON-HEALING DUE TO EXCESSIVE MOBILITY —While many lesions do not heal because of impaired trophic nerves, irritating applications, and insufficient attention, a more frequent cause is found in insufficient immobil-

ization, particularly when the infected or ulcerating area is located near a joint where constant flexion and extension prevents the part from healing. The necessity for fixation in such lesions should be emphasized Such a factor was present in the patient whose photograph is shown in Fig 72 This patient's ulcer had failed to heal over

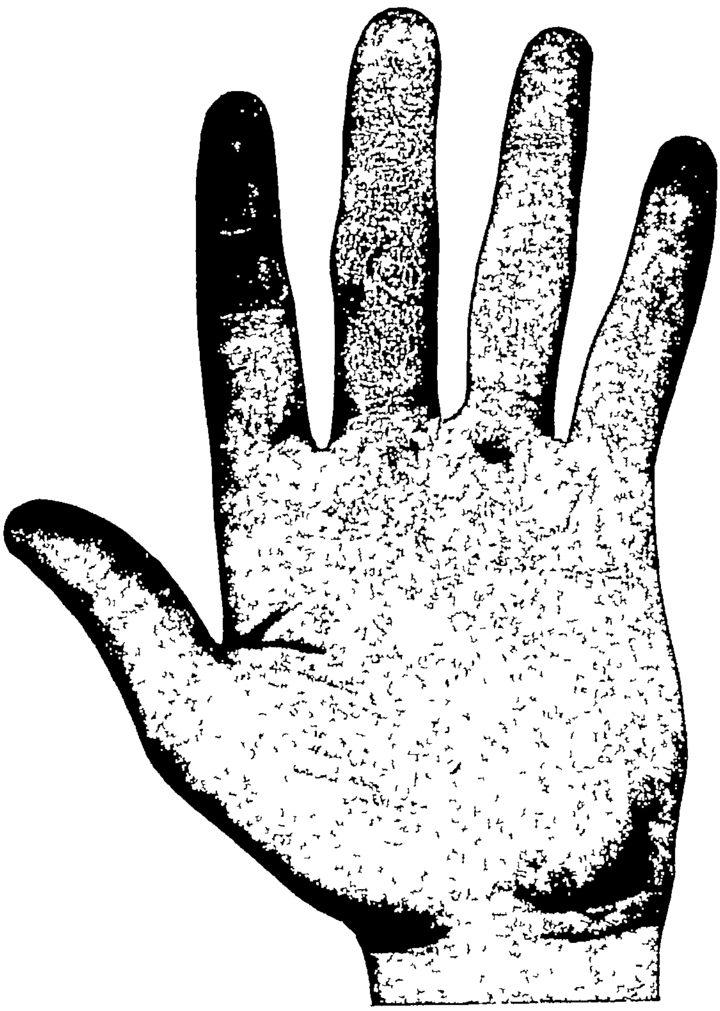


FIG 72 —Non-healing due to excessive mobility

a period of six weeks The application of a fixation splint supplemented by exposure to the drying rays of an electric light for a short time daily was followed by a rapid recovery.

Among numerous other instances found in my records in which this fundamental principle of treatment had

been violated, one case is recorded where a slight laceration on the dorsal surface of a knuckle had, during a period of eight months, been operated upon four times by curettage, undercutting of the skin with suture, and finally a skin graft with failure of cure, and another with an injury on the dorsal surface of the proximal interphalangeal joint in which, because of non-healing, an amputation had been advised. Both of these patients recovered in four weeks after immobilization and exposure to sunlight

Many other causes of prolonged disability are found that need only sound surgical reasoning to effect a cure Among these are scar tissue subject to repeated trauma, remnants of nails, bone inadequately covered by healthy skin As an illustration of the length of time these infections may persist, and the necessity for bold and adequate treatment, the following case report is an excellent example The case illustrates also the paronychia found in dye workers, and the various aerobic and anaerobic bacterial flora sometimes found in these chronic infections

Case II —Miss A K, aged twenty-two years, admitted May 9, 1932

Present Complaint —Chronic infection of nail-bed of right thumb

Present Illness —Patient originally had her thumb smashed in a door when she was four years old She was not given any attention at the time and it has been sore ever since States that she had an older sister at the time who had tuberculosis and thought that it may have been infected by the Koch-Weeks' Bacilli She cannot remember having a nail until five years ago, before this time all that she had was a crust which would come off when she washed If there were any pus pockets she would open them herself

Five years ago she worked in an overall factory and got some dye in the end of her finger which necessitated removal of part of the bone The patient was operated upon at the Grace Hospital, Detroit, by incision and scraping the bone The skin could not be closed over the incision The wound healed in a week with light therapy and mercurochrome dressings

The skin began to thicken and a nail formed in about six months

following this operation However, pus formed under the distal edge of the nail and under the skin at the base and the sides much like a paronychia If neglected the pus would travel down to the level of joint She found that by pushing the cuticle back the nail would break and she could lift it off She would then soak it in hot water, hot boric and sometimes lysol This would seem to dry it up and heal it for a period of six months The nail grew back on again in about eight months (Fig 73).

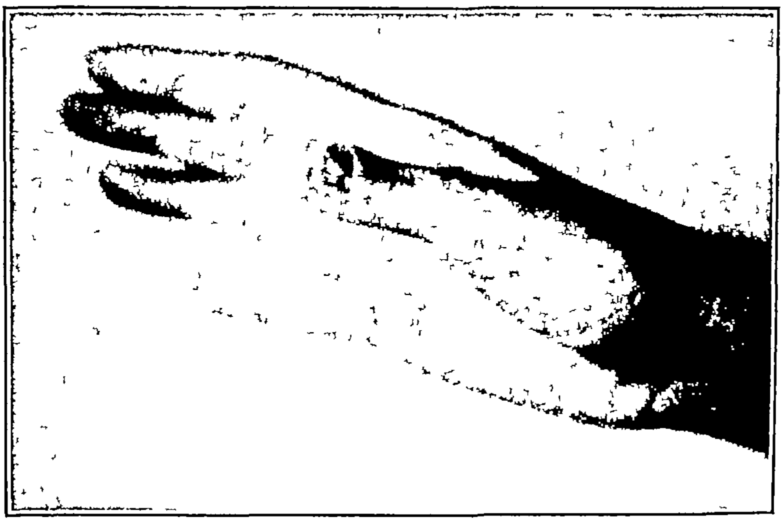


FIG 73 —Chronic infection of the nail-bed

She then saw another surgeon in Detroit, who injected a local anesthetic and removed the same amount of nail that had been previously removed eight months before He did not remove the nail-bed Following this it seemed to heal, but in a short time it became infected again

She went next to the University of Michigan Medical School, where she had it roentgen-rayed Roentgen-ray showed no bony involvement They also removed part of the nail The finger did not heal following this and she came to Chicago in April, 1931 During a few months following this she used hot Antiphlogistin This only seemed to draw pus out, so she began to soak it with Chlorozene This healed it up, but it became infected again She went to Dr Heiss, who referred her to Dr Kanavel about two months ago DR WIDNEY, *Clerk*

Laboratory Report —May 4, 1932 Cultures made from thumb of right hand show a mixed growth of the following organisms There are two strains of staphylococcus—one which is Staphylococcus albus and the other a somewhat larger coccus, which may be Staphylococcus citreus There is a short chain streptococcus present, and Gram-

positive bacillus having the morphological characteristics of a diphtheroid bacillus There is also a very small Gram-negative spore-bearing bacillus present in the anaerobic cultures which does not conform to the morphological characteristics of the common pathogens Subcultures have been made for further identification

May 12, 1932 Anaerobic subcultures made from finger show a very meager growth after eight days' incubation There are a few of the spore-forming organisms previously described present, however, the growth is so meager that no attempt was made to determine the sugar fermentation reactions The original anaerobic culture of this spore-former was tested for heat resistance Subcultures of this heated culture showed no growth after eight days' anaerobic incubation, *i e*, it is not resistant to heat

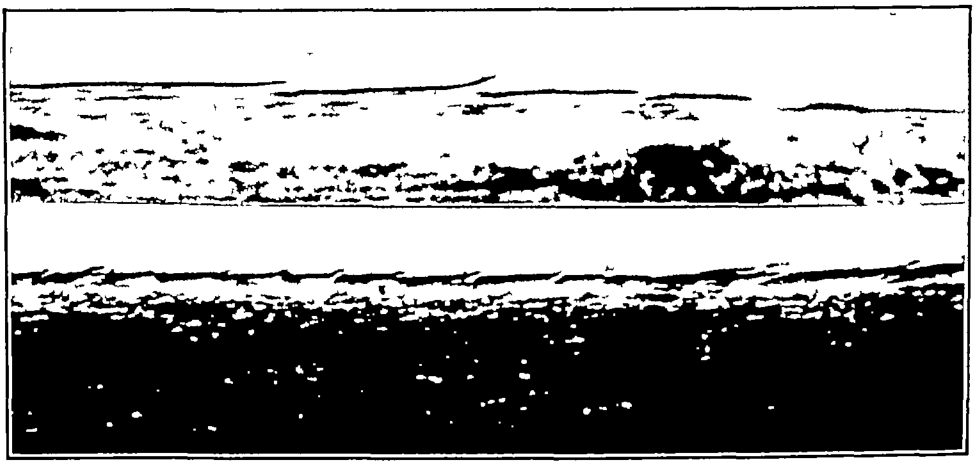
The patient was operated upon and the scar dissected from the end of the thumb under local anesthesia A small pedicled graft which had previously been freed and returned to its bed was raised and the end sutured over the denuded area A starch bandage was applied to immobilize the hand and arm The end of the flap was washed daily with soap and water and dressed The flap healed well to the thumb, and the pedicle was divided on September 21, and she was discharged on September 24, 1932, with the graft well healed and healthy in appearance.

Milker's Nodules (Cattle Hair Infections) — Under this general title are included, in all probability, two different clinical entities, invasion and chronic infection from cow hairs and infection from cow-pox.

Those lesions due to invasion of the subcutaneous tissue with cow hairs were first described by Peiser, 1908, in the *Zentralblatt fur Chirurgie* As far as I know Chase is the only surgeon in the United States who has drawn attention to the lesion, although many cases are reported in the German literature They may appear on any part of the hand, but are most commonly seen on the palm or flexor surface of the fingers where fissures in calluses offer a favorable opportunity for the introduction of hair from the udder of cows during milking, hence the title "milker's nodules" They may be found, however, in stockmen, workers in packing houses and stockyards, or others coming in contact with cattle The hairs of cattle have scales pointing toward the proximal end

that promote their wandering in the tissue (Fig 74) They may migrate to some distance producing suppuration and even osteomyelitis. Eilers reports one case in which a carcinoma developed upon such a chronic infection in the palm.

These hairs give rise to chronic infected nodules often with a granulating surface or repeated small abscesses After the abscesses are drained healing takes place, but in a few weeks or months the abscess recurs. This history may be repeated many times until the cause is



Distal end Proximal end

FIG 74 —Scales on hair from the udder of a cow Note that the scales point toward the proximal end Lower photograph, × 500, upper, × 1540

discovered and the hairs removed In industrial workers about packing houses the lesion, unless recognized and properly treated, often gives rise to unnecessary disability and prolonged compensation

The treatment offers no difficulty if the diagnosis is made, since complete removal of the hairs ends in permanent recovery

Other very similar nodules appearing on the hands of milkers have been proven to be due to pock infections emanating from the udders of cows suffering from pox This is not common in the United States

Mycotic and Toxic Inflammation —At times the surgeon sees upon the hands simple cutaneous inflammation surrounding multiple vesicles which apparently have pus or serum in them. They not infrequently appear upon the sides of the digits and have the clinical appearance of a herpes They may be parasitic or non-parasitic. While there is a growing tendency to attribute them to mycotic origin, yet there can be no doubt that

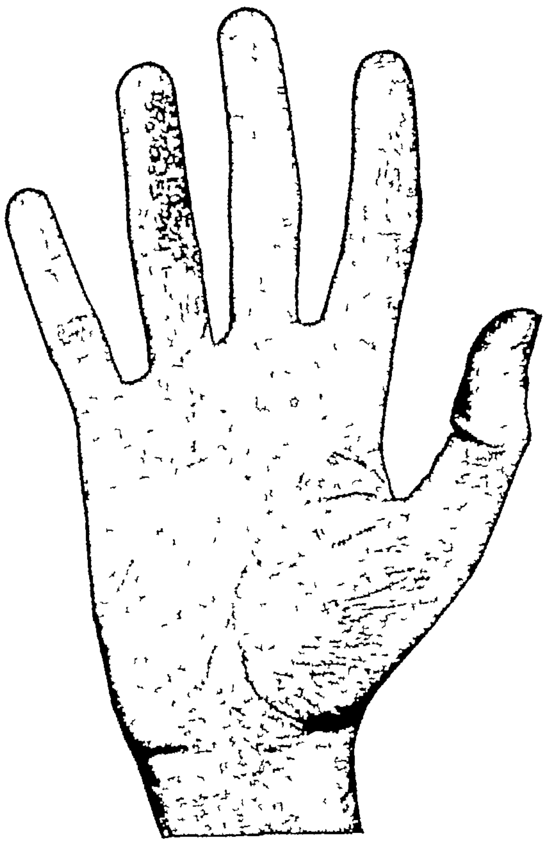


Fig 75 —Herpes in mycotic infections

many have their genesis in chemical agents, allergic susceptibility, or systemic infection They have a tendency to recur and are extremely difficult to cure and should be referred to those who have a special interest in dermatological lesions.

Besides the vesicular lesions mentioned above we find various simple inflammatory lesions occurring especially between the toes and fingers, and certain hyperkeratotic

lesions which are definitely mycotic in origin Many forms of these molds, in addition to the ringworms, are known to produce such lesions. The so-called athlete's foot is an example of these They are eczematoid in nature and respond to simple dermatological treatment. The inflammation is seldom sufficient to be confusing in diagnosis.

The preceding illustrations of many of the apparently simple lesions that lead to prolonged disability emphasize the necessity for more thoughtful attention to the apparently simple infections. May I urge upon surgeons the necessity of not relegating to internes and assistants the entire care of trivial infections, and the necessity for a periodic review by the surgeon himself of all patients in whom recovery is delayed?

DIFFERENTIAL DIAGNOSIS.

CHANCRE

By far the most common error is the failure to recognize a chancre and to regard it as a simple chronic infection Physicians especially are liable to this infection upon the fingers. It has been my experience to meet several such cases in which the lesion was unsuspected for some weeks Particularly when the infection has occurred on the distal phalanx and about the nail, other causes have been assigned When we see a lesion beginning as a simple low-grade process leading to a granulation tubercle giving little pain and failing to heal promptly, an investigation as to the possibility of syphilis should be instituted and a search for the Spirochæta pallida made.

TULAREMIA, SPOROTRICHOSIS, AND COCCIDIOIDAL GRANULOMA

In addition to the local lesion these infections extend by the lymphatic channels and present pathological

lesions of the glands, sometimes ulceration, and have been mistaken for chronic staphylococcic processes.

TULAREMIA.—The Bacterium tularense was first discovered and named by McCoy and Chapin They found it as a cause of an epidemic disease among ground squirrels in Tulare County, California In Utah the disease was known clinically as deer-fly fever. Francis, to whom we owe most of our knowledge of the disease, demonstrated its origin from rabbits and named the disease It is transmitted to man by the bite of an infected blood-sucking insect or tick or through direct contact with the blood or infected tissue of the diseased rodent It, therefore, is seen most often on the hands of hunters, market-men, cooks, and laboratory workers It may gain entrance through the intact skin The disease manifests itself in the typhoid and glandular types.

In diagnosis the following tetrad is to be borne in mind.

1 History of contact with rodents, especially rabbits, and frequently an injured hand

2 Infection following insect bites (in western states).

3 Persistent glandular enlargements

4 Fever of two to three weeks' duration.

The primary lesion appears as a papule, reddish in color, usually on the hand, together with severe systemic manifestations followed almost immediately by swelling and tenderness of adjacent axillary or epitrochlear lymph glands Lymphangitis may accompany the glandular swelling. The primary lesion progresses rapidly with a breaking down of the center and extrusion of a necrotic core, leaving an ulcer about ¼ inch in diameter with raised edge and a punched-out appearance The fever may be sustained or have daily remissions and reach even 104° F, and often lasts for three to four weeks In about one-half the cases the lymph glands break down or they may remain hard and tender for

two or three months. Agglutination with the Bacterium tularense appears in the second week.

The treatment is symptomatic although the serum from previously infected individuals may be of value. Surgery is not indicated Death is rare, but the convalescence is slow with persistent weakness

Sporotrichosis —Cases of sporotrichosis have been found throughout the country, particularly in rural districts where it not infrequently occurs following a trivial injury while handling plants or shrubbery, particularly the barberry brush

The lesion first appears as an elastic, subcutaneous nodule, not adherent to the overlying skin. As it increases in size, however, which it does to a diameter of 1 to 2 inches, it becomes adherent and the skin over it bluish-red in color

We often find one or more sharply circumscribed, painless, chronic subcutaneous abscesses along the course of the lymphatics There are few inflammatory manifestations The differentiation from tuberculosis, syphilis, tularemia and other chronic lesions must be made by identifying the organism

The treatment consists in opening the abscesses, cleaning them and giving large doses of potassium iodide internally

Coccidioidal Granuloma —This relatively rare disease, caused by infection with the Oidium coccidioides, is reported most frequently from California, particularly the San Joaquin Valley It is probably transmitted through an intermediate host, likely an insect bite The local lesion is suggestive of tuberculosis or blastomycosis. It differs from blastomycosis, however, in that the lymph glands become infected

The diagnosis is made by finding the organism in the secretions or the sections of the diseased tissue

In the early stages a cure may be obtained by local

excision, but after generalized infection the termination is usually fatal within a matter of weeks or months at most Jacobson reports improvement in some cases with injections of colloidal copper, especially one located on the dorsum of the hand.

BLASTOMYCOSIS, ACTINOMYCOSIS, AND ORIENTAL BOIL

These infections seldom present the glandular involvement of the lesions just discussed. They may at times be mistaken, particularly early in their course, for inflammatory lesions

BLASTOMYCOSIS (OIDIOMYCOSIS)—Blastomycosis may be confused with chronic staphylococcic ulceration The appearance of such a lesion is, however, very characteristic and is found principally on the dorsum of the hand The initial lesion is an intradermic nodule somewhat resembling that of an acne This becomes a small abscess from which pus can be expressed and it is these multiple small abscesses at the periphery of the lesion which are characteristic The process spreads irregularly, the edge becomes undermined with a moth-eaten appearance, thick crusts form from the seropurulent discharge, and areas of healing appear from the incompletely destroyed epithelium

The diagnosis can be made by identifying the organism in the unstained smear of pus diluted with 4 per cent KOH or with normal salt solution This finding may be supplemented by microscopic examination of the skin, which shows the proliferating rete with miliary abscess

The treatment consists of complete excision followed by increasingly large doses of potassium iodide

ACTINOMYCOSIS—The appearance of actinomycosis on the hands is seen in a small percentage of its total incidence A great percentage of these cases occurs following injury of the hand on the teeth of an opponent in a fight The fungus grows in closely-packed clumps, yellow in

color, is too large to invade the lymph channels, and has a preference for subcutaneous and connective tissues. In the early stages the disease is slowly progressive, relatively painless, and manifests itself in a markedly indurated lesion which may be confused with a tumor growth. Skin ulceration is not large, but frequently there is widespread undermining with rupture to the surface at numerous places.

Treatment consists of drainage and evacuation of abscesses with a scraping of the interior, and large doses of potassium iodide beginning with small doses and working up to several hundred grams daily.

Oriental Boil —While most often found around the Mediterranean, Persian Gulf and Indian Ocean, Oriental boil is occasionally encountered here. It supposedly occurs following an insect bite and may be suspected from the chronicity and duration of the lesion and history of possible exposure in regions where the disease is endemic The patient complains of attacks of irregular fever followed by one or more small papular lesions appearing on the skin with red, small, indurated centers and inflamed areolæ After several months ulceration ensues, the secretions dry and form a hard, adherent crust Conclusive diagnosis can be made by demonstration of the organism in a smear or culture.

Treatment consists of tartar emetic by intravenous injection as a 1 per cent solution in water or normal saline, which should be freshly prepared, also freezing with carbon dioxide and roentgen-ray may be tried

ANTHRAX

Anthrax is not common in the United States, although sporadically it may appear in various sections The frequency of lesions upon the hand and arm is given by Koch, in a series of 923 cases, as 40 per cent Personally, my experience is limited to 1 case The description of

the condition which I append is modified from that given in Frazier's excellent description of the disease. No attention, of course, is here given to the pulmonary and intestinal types When the disease is implanted upon the hand or forearm of those having to deal with hides and other sources of infection, we note an elevated pustule, 5 mm to several centimeters in diameter, with a depressed central scab The corium and papillary body become infiltrated with a serocellular exudate and with bacilli The perivascular and connective-tissue spaces become filled with leukocytes, and the pressure of this serous and cellular infiltrate, together with the toxins of the bacteria, cause the central coagulation necrosis, though suppuration does not occur unless there is a mixed infection When the serocellular exudate extends upward to the superficial epithelium, it elevates the latter and produces the typical vesiculation In the edematous variety the swelling is due to the diffuse serocellular infiltrate and to the effect of the bacteria blocking or inducing coagulation in the capillary vessels.

The lesion may be transferred to other parts of the arm or body, especially the face, by scratching the lesion and then the secondarily infected part Wherever the lesion occurs we note that from a few hours to some days after the inoculation some itching and burning are felt, and upon inspection a small papule with a central bluish point is seen A few hours later the papule becomes vesiculated, contains a brownish, sanguineous fluid, and may be scratched off by the patient The surrounding tissues become red, indurated, and puffy, and later purplish and gangrenous in appearance, although there may be no indication of suppuration Pain now ceases, and beyond malaise, nausea, slight fever, and muscular or joint pains, there may be no other constitutional effect. A vesicular areola limited in extent is soon observed about the pustule, containing serohemorrhagic fluid, the pustule

may undergo necrosis, the area of necrosis rarely exceeding 3 cm in diameter. In about ten days, in favorable cases, a line of demarcation forms about the eschar, which "floats off," leaving the defect to heal by granulation In more severe cases the edematous swelling about the pustule may be very extensive and erysipelatous in appearance, associated with a lymphangitis and lymphadenitis with hard and tender lymph nodes. The vesicles become bullæ, contain a bloody fluid, and the ultimate suppurative and gangrenous process may involve areas as large as the entire half of the face In these severe cases the constitutional symptoms are marked, resembling those of cholera, with great prostration and depression, a weak, rapid pulse, often icterus, diarrhea, delirium, and coma

In the parts where there is considerable loose areolar tissue, as the eyelids, neck, and forearm, great edema may be seen Here, instead of the characteristic changes described above, the area may have a well-defined border without vesiculation, redness, or gangrene There may be little or no pain, even in those cases ending fatally.

The diagnosis must be made from the furuncles and carbuncles The careful surgeon will at once note that the lesion is essentially different from these, and will by smears and culture determine the presence of the anthrax bacillus

The statistics as to the mortality vary greatly, being from 6 to 30 per cent Koch collected 1413 published cases, with a mortality of 32 per cent

The treatment of anthrax should consist essentially in the administration of anthrax serum (60 to 200 cc.) and in the use of large amounts of water internally, and possibly in the excision of the pustule, preferably by the cautery knife If recognized early the serum should be administered subcutaneously and the pustule should be excised only when the surrounding tissues are not very

edematous, taking the precaution to cauterize the exposed surfaces with carbolic acid or the actual cautery. If the edema is marked, absolute rest of the part should be enjoined and local hot antiseptic fomentations, such as bichloride of mercury, applied. The serum has no deleterious effects, and in the hands of its originator and others, especially in Italy and England, the results substantiate the claims which have been made. In severe cases or late in the disease it may be given subcutaneously. A serum may be obtained from the United States Bureau of Animal Industry, Washington, D. C., or pharmaceutical houses. It assists in the destruction of the bacilli before they become so numerous that their destruction by the bodily defenses increases the danger of fatal poisoning from the toxins set free by the disintegration of the bacilli. When the serum cannot be obtained, and when excision is impracticable, injections of carbolic acid (5 per cent) should be tried, introducing the needle at several points along the margin of the pustule and infiltrating the base of the pustule and surrounding healthy tissue. These injections may be repeated frequently. Brentnall believes the daily injection of salvarsan or its congeners is beneficial. Scholl, Brentnall, and others believe from statistical studies that patients recover more promptly under non-surgical treatment. The constitutional symptoms must be met by appropriate and supportive measures.

CHAPTER XII

ABSCESSES IN MINOR SPACES

COLLAR-BUTTON ABSCESS (SHIRT-STUD ABSCESS) (FROG FELON).

AMONG the local infections of the hand none is more typical than the collar-button abscess, or, as the French described it, *en bouton de chemise* This may be seen in the distal phalanx but its typical location is at the distal edge of the palm under the dermal and epidermal tissues Its peculiar character is due to the fact that at this site, in workingmen, the epithelium becomes markedly hypertrophied, making a dense sheet under which the pus spreads An infection present under the derma passes through this to the epidermal tissue, where a second abscess forms, thus producing a dumbbell-shaped accumulation of pus The pus may locate primarily in the epidermic space and erode through the dermal tissue rather than through the dense epidermis to the surface, producing the same condition It is possible that this latter course is more common than the former

These abscesses doubtless owe their origin to the lessened resistance due to trauma more than those developing elsewhere, for here the thickened area of superficial cornified epithelium is frequently opened by cracking, infection ensues in the deeper area by lymphatic extension, or, if the cracks are deep, by direct inoculation Here it finds excellent food for development, since the repeated trauma has lowered the normal resistance found in healthy tissue

In this connection attention should be drawn to the fact that at the lower or distal end of the palmar aponeu-

rosis the sheet may become very thin in spots, particularly between the processes which blend with the tendon sheaths and the superficial transverse ligament, and hence above the canal for the lumbrical muscles Here, by noting one's hand, slight elevations of tissue may be seen, cushions of fatty tissue. Shirt-button abscesses may enter this fat space and spread down into the cellular tissue of the web pointing on the dorsum between the bases of the fingers. Then the dumbbell abscess would have from its second chamber a connection with a still larger one on the dorsum, a sort of chain of lakes of pus (Fig. 76).

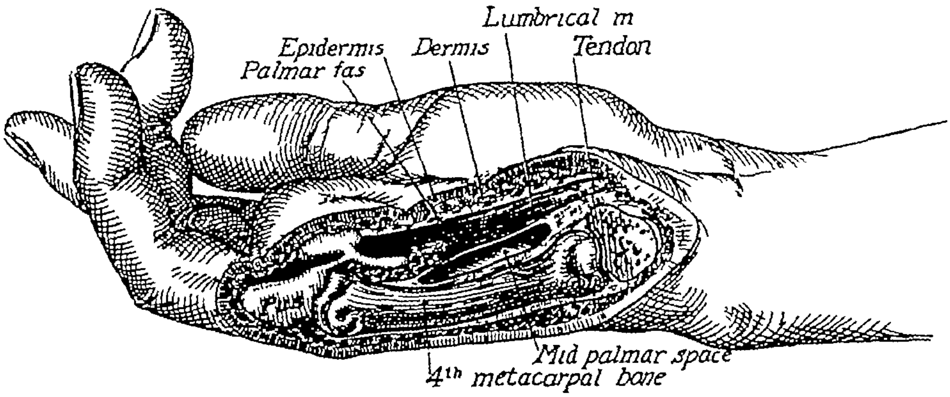


FIG 76—Schematic drawing, showing distal palmar abscess and its extension into the dorsal tissue between the fingers

In relation to this, two very interesting cases can be cited, showing how infection apparently in nearly the same site may occupy different spaces.

CASE III—From Northwestern University Medical School Dispensary History. C B, carpenter by trade, has been using a chisel several days in succession almost constantly He hits the handle of the chisel with the palm of the hand to force it along Two days ago the patient began to note tenderness at the distal portion of the palm between the base of the index and middle fingers, about 2 cm. from web Upon examination this was found to be tender to pressure, and had considerable local hardness Slight edema of dorsum Temperature, 99° F; pulse, 85

Treatment—Incision was made over the area and a small amount of pus evacuated This was under the deeper layers of skin lying upon the transverse fascia in the pad of fat found in this region

CASE IV —E A Applied to dispensary of Northwestern University Medical School The patient noticed pain and tenderness at base of ring and middle fingers, about 1 5 cm from web Swelling and redness had been increasing for four days Temperature, 99° F, pulse, 86 Local swelling and redness at site noted, involving web also, but most marked above Tenderness noted as severe

Diagnosis —Abscess, subdermal, above aponeurosis *Operation* ethyl chloride spray, and incision made over site of greatest tenderness, down through deep layers of palmar skin Moderate amount of pus escaped, and upon inserting probe the larger part of the pus was found to be in the cellular tissues of the dorsal web area, a half inch back from web Through-and-through drainage inserted Four days later the infection was practically cured and the patient did not return

Here we see two abscesses to all appearances in the same place, yet in reality very different, being so near the distal edge of the transverse ligament that while one was confined to the subdermal tissue, the second had invaded the adjacent cellular tissue of the web, and spread, by continuity of spaces, into the loose tissue of the dorsum, where most of the pus was localized

TREATMENT —The treatment, therefore, consists in being certain that the second pocket is opened if it be present, and not being content when after incising free discharge of pus is noted Always examine carefully by inspection or a probe for the second pocket If the pus has extended to the space in the web, it may be drained by a through-and-through incision from the palmar to the dorsal surface through the web I have at times cut the web completely without noting any subsequent impairment of function

LOCALIZED ABSCESSES IN THE THENAR AND HYPOTHENAR SPACES

In the thenar region several minor and indefinite spaces lie beneath not only the skin, but also the fascia which covers the muscles The areas are small, however, and are generally opened through the adjacent skin before any

serious damage occurs It is in these areas more often than the thenar space proper that direct infection from puncture takes place, since the latter lies rather deeply, and to invade it the puncture should enter between the muscular body and the adduction crease, rather than upon the prominent part of thenar eminence. It is well to bear this in mind in making a diagnosis as to whether the thenar space is involved or not, since a minor infection in the superficial tissues of the thenar area either upon the palmar or dorsal surface may be associated with great edema upon the dorsum, and thus confuse the surgeon and lead to a diagnosis of pus in the thenar space when it is uninvolved This error occurred in one of my cases, and is of particular interest, since it demonstrates that treatment based upon this improper diagnosis may not produce serious results, for here it will be noted that no disastrous sequelæ followed the opening of the uninfected space in conjunction with an abscess of the subcutaneous tissue.

Case V—E K Injured December 12, at stockyards, by running foreign body into thenar eminence at about middle of palmar surface All signs of localized infection followed, and on December 16 patient applied to dispensary for treatment Diagnosis of infection of the thenar space made and through-and-through drainage of thenar areas instituted, under gas anesthesia It was seen that only the dorsal subcutaneous tissue contained pus, tube was withdrawn and dorsal opening enlarged Patient made rapid recovery and was discharged in ten days, apparently fully recovered

The hypothenar area is a closed space, as will be shown later Involvement of this space is uncommon and when it does arise it has its origin through direct implantation It does not spread out of the space Therefore there is nothing peculiar in its pathology and the treatment of its abscesses consists in simple incision

CHAPTER XIII

INFECTIONS ABOUT THE METACARPO-PHALANGEAL JOINT.

A Study of the Routes of Extension of Infection with Special Consideration of Injuries from Teeth and Contamination of the Wounds with Organisms from the Mouth (Bites)

WITH the exception of furuncles and carbuncles on the dorsal surface of the hand and proximal phalanges there are no infections which so commonly involve these areas as those resulting from injuries by human teeth. The routes of extension from any cause are the same and the principles here presented apply to all infections but the common occurrence of fist fights and broken knuckles and the long-continued infection and marked impairment of function that so often follow such injuries make them of unusual interest, therefore, the present chapter deals primarily with this type of injury.

My associates Drs. Mason and Koch became interested in the subject, analyzed the cases which had been under our care and made exhaustive anatomical and experimental studies. These observations are published[1] and the present chapter expresses their views of the pathogenesis and treatment.

Human bite infections present such a typical course that it is apparent that there are several factors present which combine to produce a unique chain of symptoms. Although emphasis has been placed on the symbiosis of the spirillum and fusiform organisms of Plaut-Vincent,

[1] Mason, M. L., and Koch, S. L. Human Bite Infections of the Hand, With a Study of the Routes of Extension of Infection from the Dorsum of the Hand, Surg., Gynec. and Obst., 1930, 51, 591–625.

little attention has been paid to two other important factors—the exact site at which and the depth to which the infectious agent is introduced into the tissues, and the anatomical arrangement of the joint capsules and of the fascial layers of the dorsum of the hand which is the predominant factor in determining the extension of infection from the site of primary involvement

A number of reports have appeared dealing mainly with the pathology and bacteriology of the condition Hultgen, 1910, Peters, 1911, Hennessy, Madras and Fletcher, Pilot and Meyer, Fuller and Cottrell, and others have reported cases of human bite infections. Flick, in 1929 and 1932, gave in considerable detail the pathology in instances of human bite injury His observations were amplified by Owen and by Meleney Bates has recently reported a large number of cases from three Philadelphia dispensaries The synergistic action of organisms in these cases and in gangrenous processes is considered in the next chapter

MODE OF ENTRANCE OF THE INFECTION

The manner in which the wound has been received is of considerable significance in the subsequent extension throughout the tissues of the hand Most frequently the tooth penetrates the skin directly over a metacarpophalangeal joint, usually of the index or middle finger of the right hand The hand doubled into a fist, with the skin and extensor tendon stretched tightly across the joint, comes into contact with the tooth, which usually penetrates the joint cavity Because of the flexed position of the fingers the infectious agent is introduced at a point proximal to the attachment of the tendon to the joint capsule When the finger is extended the original line of entrance is sealed off by the skin and tendon as they glide proximalward This mechanism is illustrated in the lateral roentgenogram of an experimental injec-

tion of a hand (Fig 77) The infectious agent is at once introduced into three spaces—the joint space, the dorsal subcutaneous space, and the dorsal subaponeurotic or subtendinous space between the tendon and the capsule,

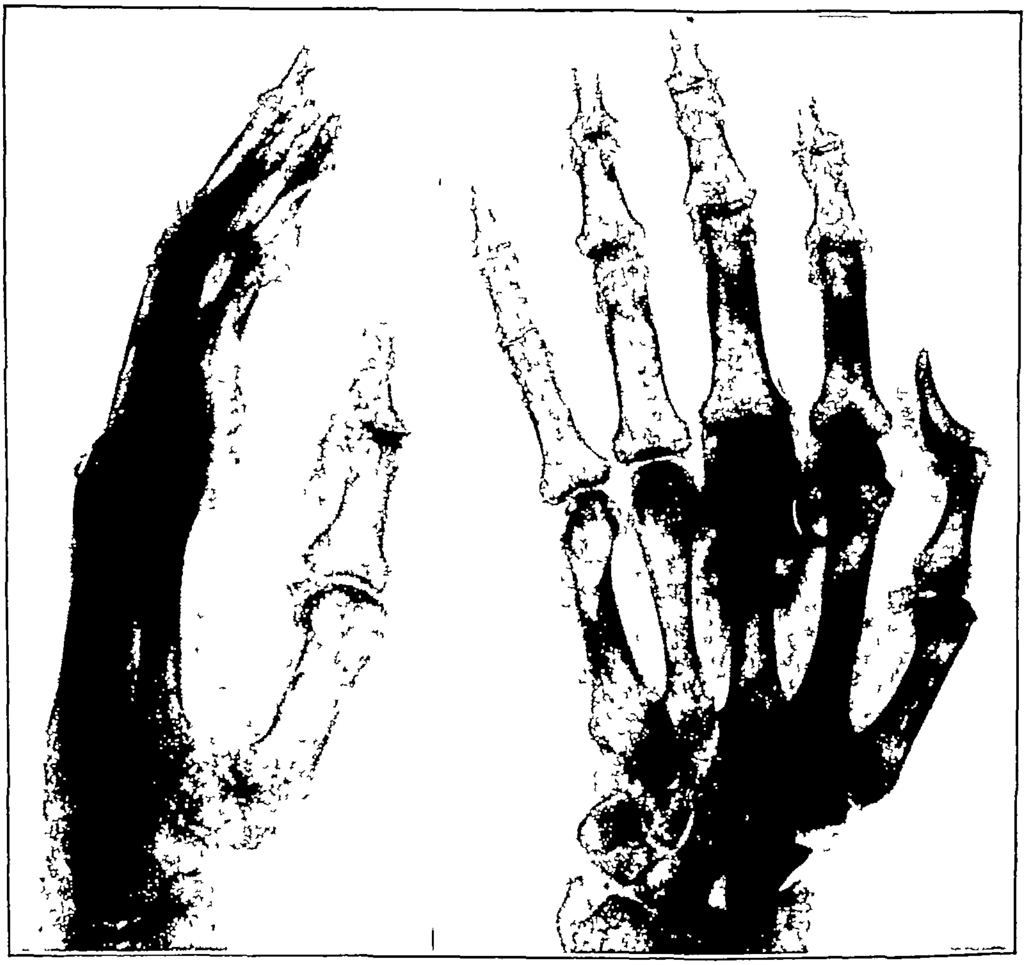


FIG 77—Roentgenogram of experimental hand No 1 in which injection of barium sulphate was made into the flexed third metacarpo-phalangeal joint After injection the finger was extended The lateral view shows the curvature of the needle tract resulting from extension of the finger, which seals the tract effectively The injection mass which has ruptured from the joint has spread proximally into the subaponeurotic space over the metacarpus (See Fig 78)

where a subtendinous bursa is usually found At times the injury is received on the proximal phalanx, in which case infectious organisms may be deposited both superficial to and under the expansion of the extensor tendon on the finger Less frequently the injury involves the

space on the dorsum between the heads of two metacarpals In such a case the infectious process develops

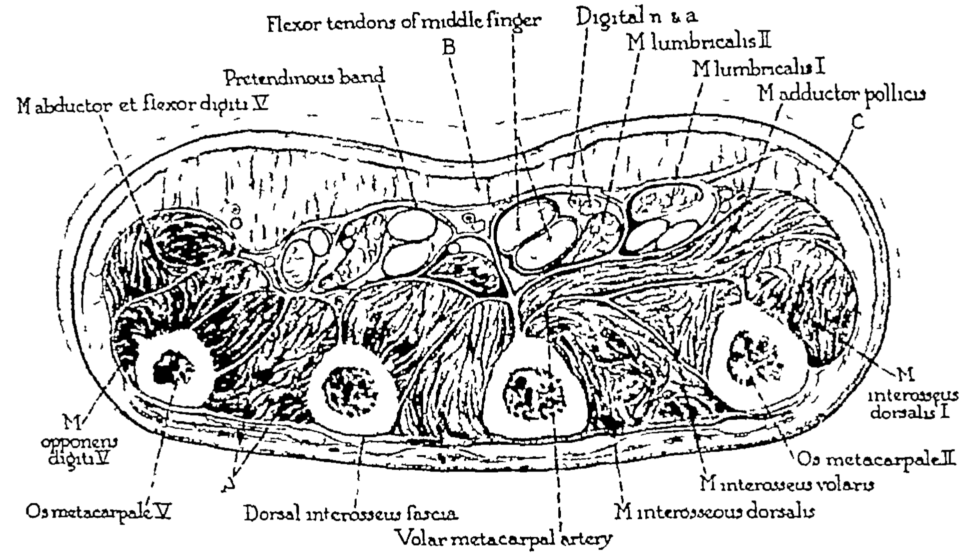


FIG 78

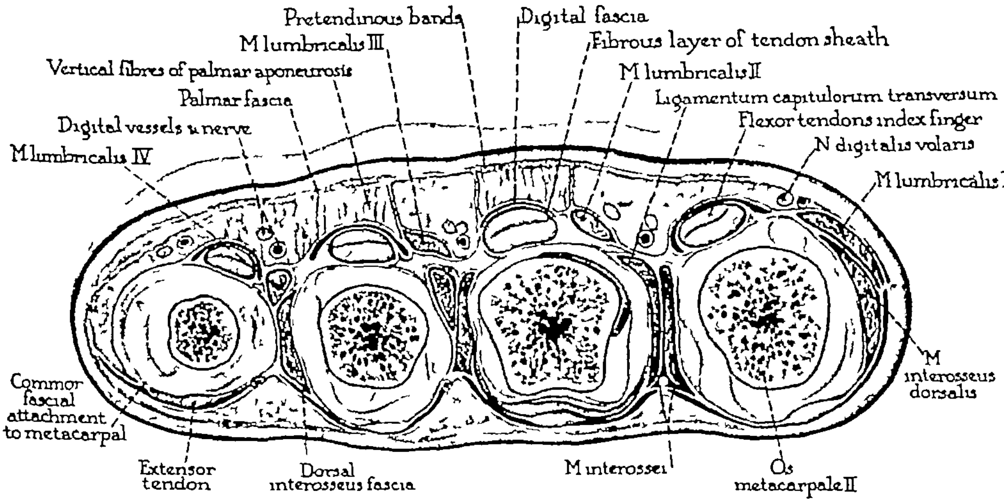


FIG 79

FIGS 78 and 79 —Cross-sections of experimental hand No 1 The extent of spread of the injected barium mixture is indicated in red In a section taken just proximal to the heads of the metacarpal bones (Fig 78) the injection mixture is seen to have filled the subaponeurotic space and to have infiltrated the interosseus muscles In a section passing through the metacarpo-phalangeal joints (Fig 79), the material is seen to lie within the joint cavity as well as external to the joint under the extensor tendon, which is directing it volarwards.

in a loose areolar space in potential communication with any of the other fascial spaces of the hand With

actual bite wounds the infection may enter at any location and may be associated with avulsion of a variable amount of crushed and macerated tissue

After gaining entrance into the subcutaneous tissues, extension of the infection is determined by the anatomical arrangement of the tissues The spread, however, is not entirely determined by the continuity of one fascial space with another, but also by the involvement in the process of thin fascial sheets, which when infected lead to extension throughout the spaces of which they form the covering

Dissection of the hand, with especial attention to the region of the metacarpo-phalangeal joints, show that at this region there is a convergence of vessels, tendons, and fascia which come from both the volar and dorsal surfaces The anatomy of the joint capsule itself is also of importance

ANATOMY OF THE FASCIA ABOUT THE METACARPO-PHALANGEAL JOINTS

Most of the fascial layers of the hand possess some attachment at the region of the metacarpo-phalangeal joints The dorsal subcutaneous fascia, which is very loosely attached to the extensor tendons, passes over the joints to become continuous with the superficial digital fascia and dips into the interdigital spaces to fuse with the superficial fascia of the palm The dorsal subcutaneous fascia is also attached to the deep digital fascia, a structure which has certain anatomical and clinical interest The deep digital fascia, which splits to enclose the digital vessels and nerves, is attached laterally to the sides of the phalanges (Figs 92 and 93), thus forming a barrier to invasion of the tendon sheath from dorsal infections, fuses in the digital clefts with the dorsal interosseous fascia and the fascia between interosseous muscles (Fig 79).

The potential spaces found upon the dorsum of the fingers are of considerable importance in the spread of infectious material (Figs. 92 and 93) The space between the skin and superficial fascia is restricted by the attachments of the skin and fascia, hence spread here is limited



FIG 80 —Roentgenogram of experimental hand No 3 A moderately forceful injection was made into the metacarpo-phalangeal joint of the middle finger, and is seen to have ruptured out into the tissues just proximal to the joint

Between the superficial and deep digital fascia the attachments are less dense though they do limit somewhat the extension of infection The attachments between the deep digital fascia and the extensor tendon, however, are very lax, allow free movement of the tendon, and hence infectious material here spreads without much

obstruction The fascia sheets lead it volarward and into contact with the neurovascular tunnel leading into the palm. Since the lumbrical and interosseous muscles attach to the extensor tendons, these also would lie in direct contact with the infection The space between the extensor tendon and the bone is also a loose one and an abscess here is carried volarward, though the attachment of the tendon to the sides of the phalanges tends to prevent it from encircling the finger

The extensor tendon inserts into the base of the proximal phalanx and distal portion of the metacarpo-phalangeal joint capsule by a set of rather stout fibers Between

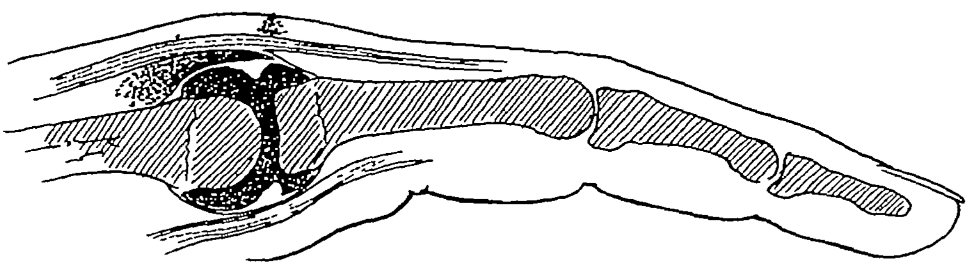


FIG 81 —Longitudinal section through experimental hand No 3 shows that the injection mass has filled the joint space and has ruptured the dorsal part of the capsule over the head of the metacarpal and has extended into the subaponeurotic space

the extensor tendon and the joint capsule and proximal to the tendon insertion there is usually a small, thin-walled, subtendinous bursa When the hand is clenched into a fist the knuckles are covered by the taut extensor tendons and the underlying bursa Infectious material introduced into this subtendinous space would therefore involve the bursa and by extension from the bursa involve also the dorsal subaponeurotic space

The attachments of the joint capsule are also of interest in the study of extension of infection from the metacarpo-phalangeal joints Surrounding the synovial membrane is a dense fibrous capsule, condensed into several definite thickened bands, between which the thinly

covered synovial membrane may be made to bulge by appropriate injection of the joint space On the volar surface of the joint is a thick, often cartilaginous plate, over which glide the flexor tendons This plate is securely

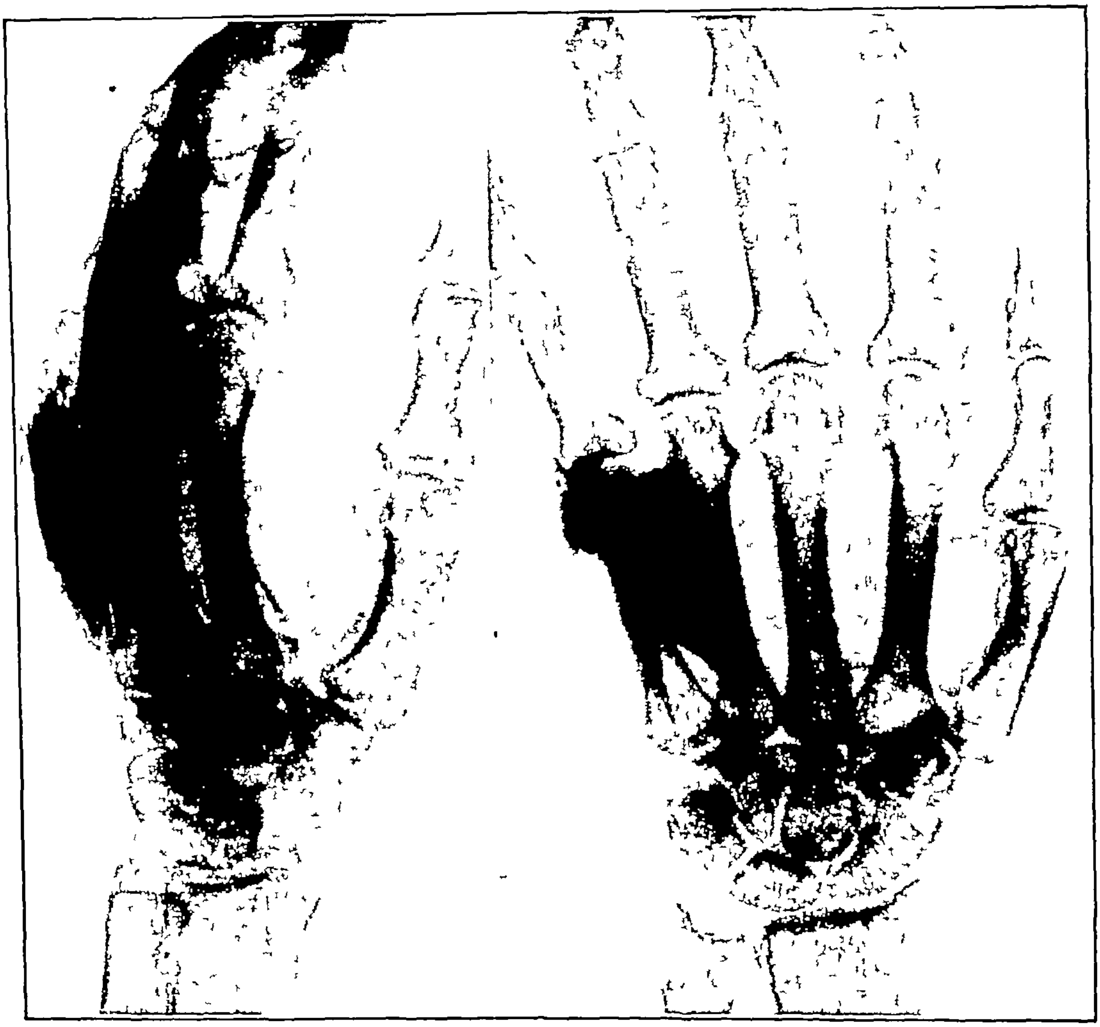


FIG 82 —Roentgenogram of experimental hand No 9 The barium mixture was injected into the subaponeurotic space just proximal to the fifth metacarpo-phalangeal joint A thin, though definite, attachment of the aponeurosis has prevented the mass from spreading farther radialward than the mid-line of the fourth metacarpal bone, though it has spread proximally almost as far as the carpo-metacarpal joints

attached to the base of the proximal phalanx, but is quite loosely attached to the metacarpal bone, so that this proximal and volar portion of the capsule may be perforated easily by infectious processes in the joint

Along the lateral sides of the joints are two ligaments, the collateral ligaments, which attach proximally to nodules on the dorsal aspect of the heads of the metacarpals, and distally to the condyles on the volar surface

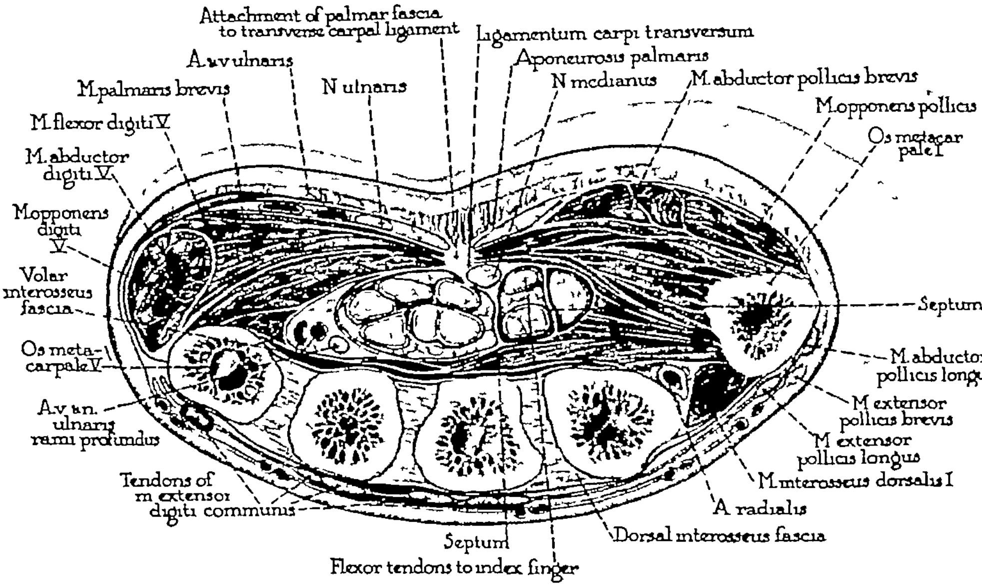


FIG 83

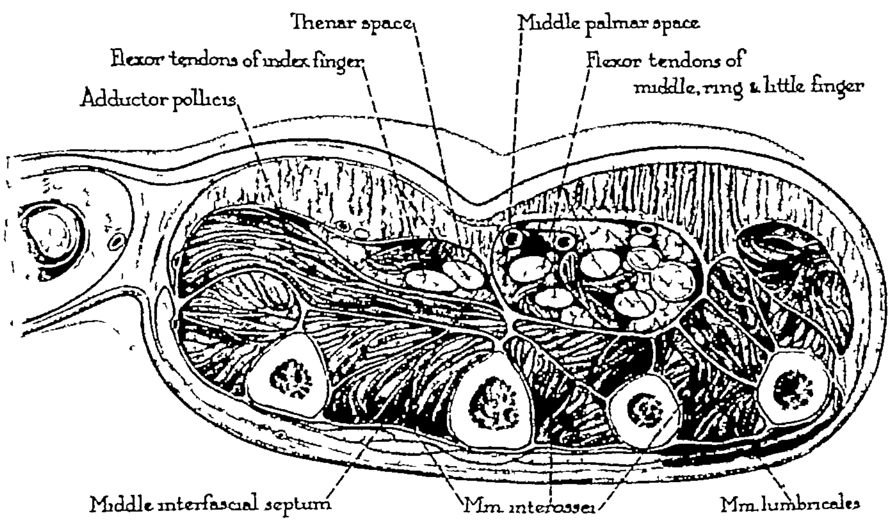


FIG 84

of the proximal phalanges, and the accessory ligaments which lie volar to the collateral ligaments, and which run from the dorsum of the metacarpal bone to the thick volar plate There is a weak spot in the joint capsule

between these two ligaments, through which the condyles of the metacarpal bones covered only by thin synovial membrane can often be seen The joint capsule is loosely attached dorsally to the head of the metacarpal bone,

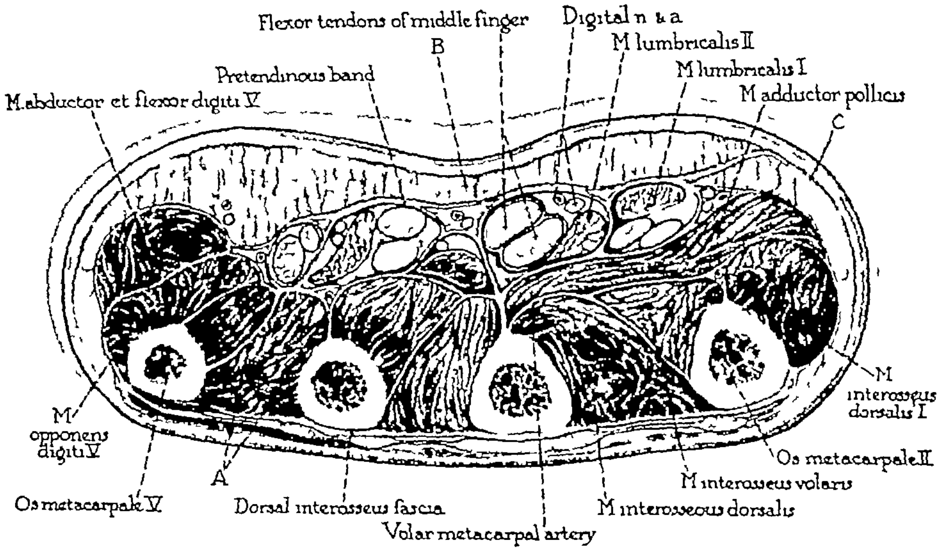


FIG 85

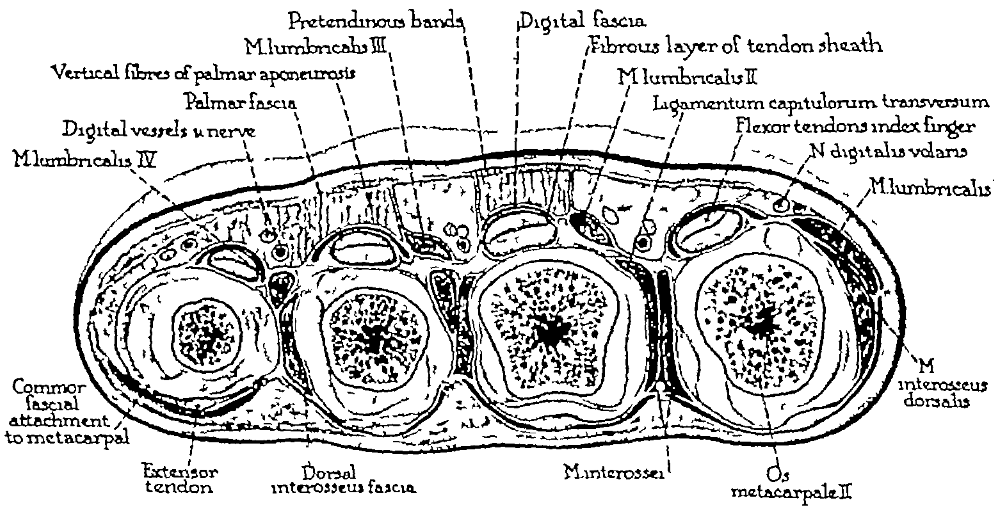


FIG 86

FIGS 83 to 86 —Cross-sections of experimental hand No 9 show that in the section (Fig 86) directly over the metacarpo-phalangeal joint the barium lies in the subfascial but not in the subaponeurotic space Further proximally barium is seen to occupy both the subfascial and subaponeurotic spaces limited in both sections (Figs 84 and 85) to the spaces ulnar to the mid-line of the fourth metacarpal bone Near the wrist (Fig 83) the injection material, besides occupying the subaponeurotic and subfascial dorsal spaces, has followed an extensor tendon in a course which has separated this extension from the main mass

while its distal attachment to the dorsum of the first phalanx is quite secure Hence the dorsal part of the capsule presents little obstruction to the proximal extension of infectious material from the joint cavity

In order to test experimentally the significance of the anatomical relationships about the metacarpo-phalangeal joints, a series of injections were made of cadaver hands to determine the routes of extension of infection from the subcutaneous tissues, the flexor tendon sheaths, and the various fascial spaces of the hand Most of the injections were made into the metacarpo-phalangeal joints, one was made over the dorsum of the proximal phalanx and one in the cleft between two fingers After the hands were injected roentgenograms were made, and the hands were then frozen and sectioned transversely or longitudinally These sections were carefully studied to determine the exact location of the barium mixture It is not necessary here to go into a detailed description of each of these experiments which are reported *in extenso* in the paper by Mason and Koch, to which the reader is referred

The results of the injection experiments indicate that the course of spread of the process from infected injuries such as tooth lacerations in the region of the metacarpo-phalangeal joints, the proximal phalanges of the fingers, and the loose tissues in the web is by the following routes.

From the joint space it probably ruptures first proximally into the thin-walled bursa overlying the head of the metacarpal and underlying the extensor tendon (Figs 80 and 81) It is not confined here by the thin walls of this sac, but breaks through and gains the subaponeurotic space, through which it spreads proximally under the tendon (Figs 77, 78, 79) Its lateral extension under the tendon is hampered to some extent by the loose areolar tissues running from the under surface of the tendons to the dorsal interosseous fascia and

metacarpal bones (Figs 82 to 86) Following this subtendinous pathway it may extend proximally as far as the wrist-joint and laterally over a considerable extent



FIG 87 —Roentgenogram of experimental hand No 2 Injection made into third (middle) metacarpo-phalangeal joint This figure, when studied in conjunction with Fig 84 reveals the tremendous extension which may take place from the joint

of the dorsum As the pus ruptures from the subtendinous bursa it comes to lie in the loose areolar tissues in the proximal part of the web of the fingers and thence may spread laterally and distally (Figs 87 to 93) In

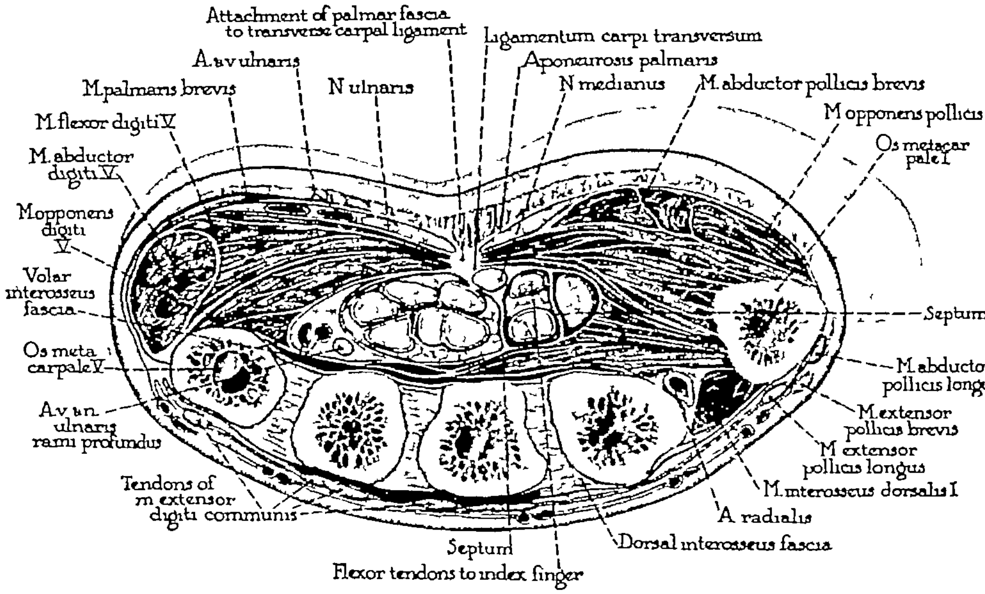


FIG 88

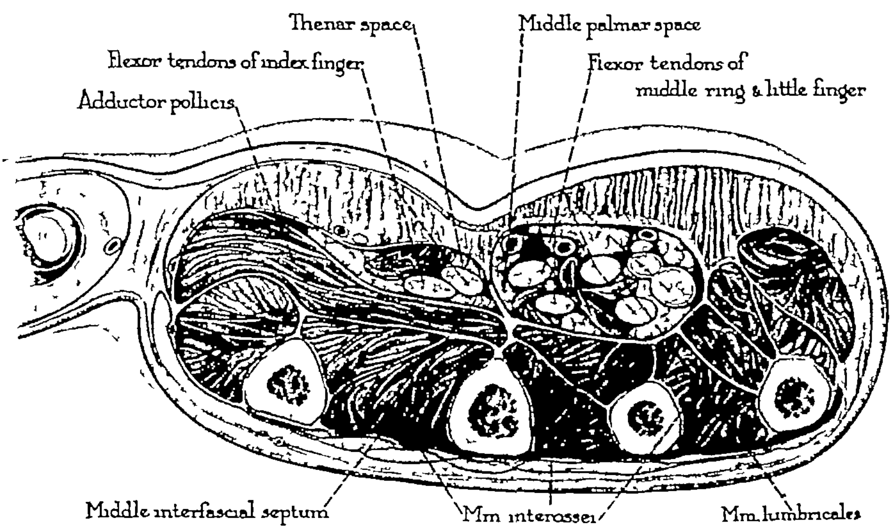


FIG 89

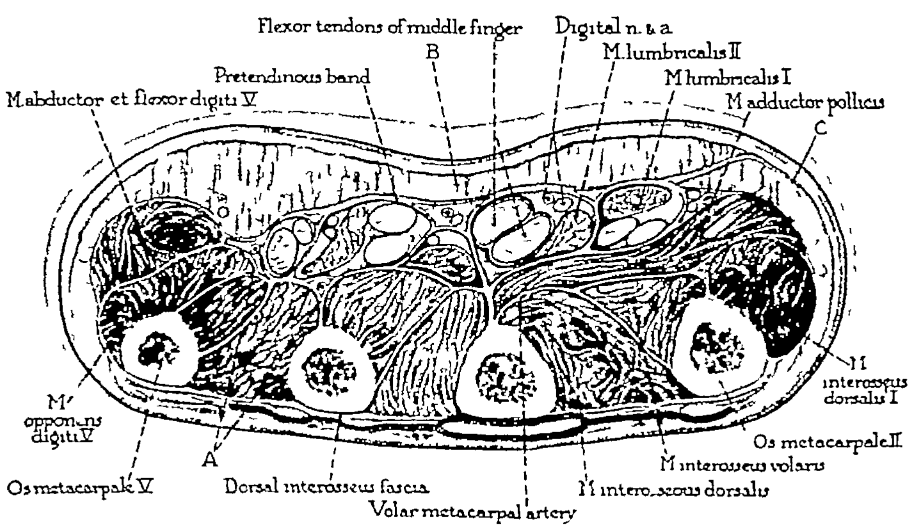


FIG 90

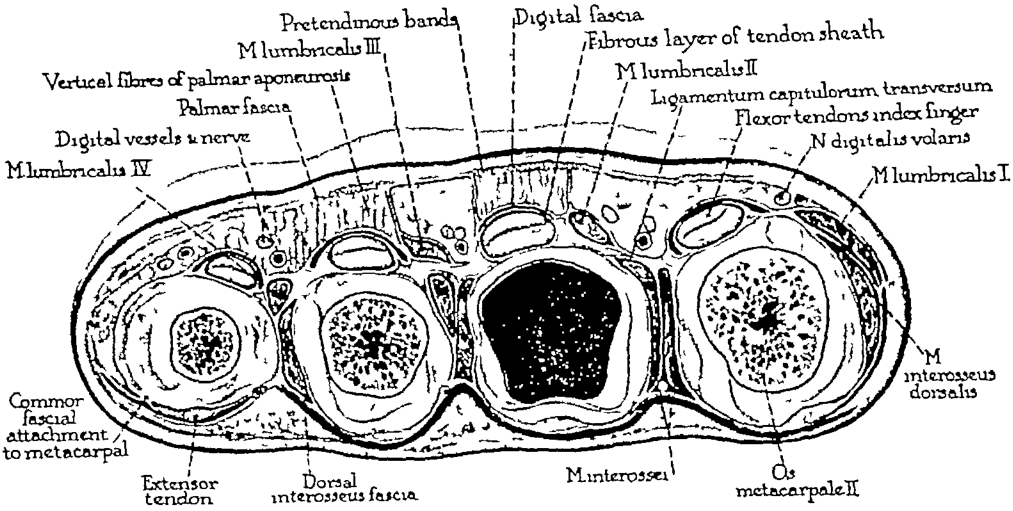


FIG 91

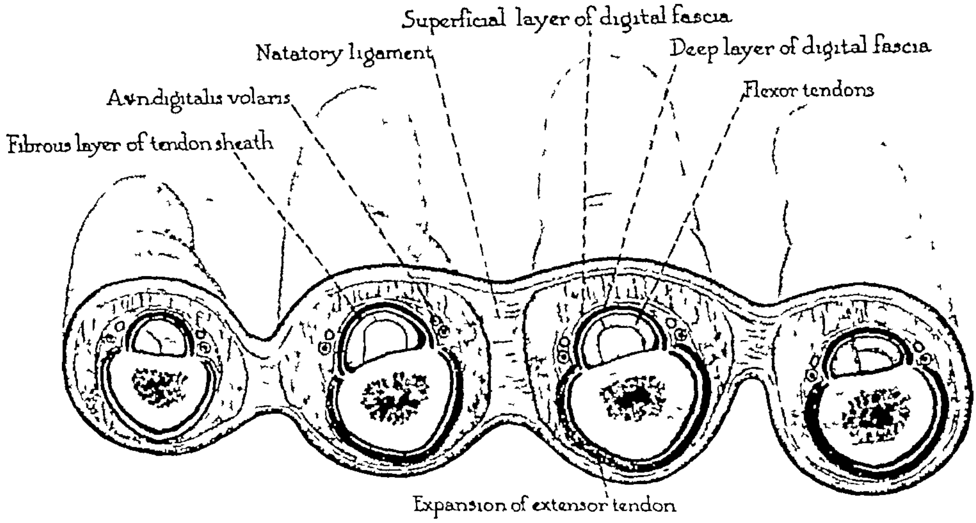


FIG 92

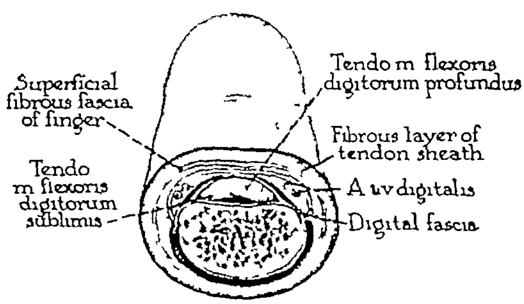


FIG 93

FIGS 88 to 93 —Cross-sections of experimental hand No 2 Fig 88 Through bases of the metacarpals Fig 89 Midway between heads and bases of the metacarpals Fig 90 Just proximal to the heads of the metacarpals Fig 91 Through the metacarpo-phalangeal joints Fig 92 Through the bases of the proximal phalanges Fig 93 Through distal part of middle phalanx The injection mass has extended proximally in the subaponeurotic space as far as middle of the metacarpus As it is traced distally it is seen that in the region of the metacarpo-phalangeal joint it appears in the subfascial space, and on the fingers it lies between the extensor tendons and the deep digital fascia It is interesting to note that the attachment of the deep digital fascia to the sides of the phalanx prevents extension onto the volar surface of the finger

this position it lies dorsal or external to the extensor tendons, and as it spreads distally over the fingers it lies between the deep digital fascia and the aponeurosis It may also spread proximalward from this position and therefore for a certain distance lie dorsal to the extensor aponeurosis over the dorsum of the hand

As it lies in the web, it comes into close relationship with the tendons of the volar and dorsal interosseous muscles (Figs 91 and 92), which are covered by a thin sheet of fascia, and it is reasonable to assume that extension into the interosseous spaces of the hand could take place along the tendons after invasion of the fascia

As was emphasized above the volar attachment of the joint capsule to the proximal phalanx is very secure and immobile, while its attachment to the head of the metacarpal bone is loose, so as to allow free movements This thin sheet of synovial membrane and fascia would offer very little barrier to extension of purulent material from the joint into the tissue lying between the metacarpal bone and the volar interosseous fascia (Fig 87)

When the infection lies in the finger between the extensor aponeurosis and the deep digital fascia it is in close proximity to the digital vessels and nerves in their fascial tunnel (Figs 92, 93, 95, 96) Although none of the material has been forced into the fascial tunnel, its walls are so thin that it would be quickly invaded by infection It is to be noted that the flexor tendons and their synovial sheaths are well protected by the dense fibrous tendon sheath, and one would not expect a tenosynovitis to occur except late in the course of the infection The lumbrical tendons which extend along the side of the finger to insert into the extensor tendon also lie in close relation to any infectious material which lies under the deep digital fascia They are covered by thin fascia which is not a very secure barrier to extension proximalward Should the process follow along one of

the lumbrical tendons it would soon reach the lumbrical canal and one of the large fascial spaces of the palm (Figs 94 to 98)



FIG 94 —Experimental hand No 5 Injection was made underneath the extensor tendon on the proximal phalanx of the ring finger The barium has extended both proximalward into the hand and distalward along the finger

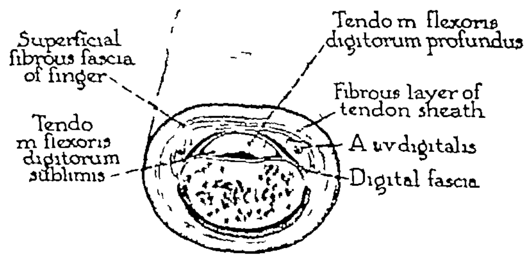


FIG 95

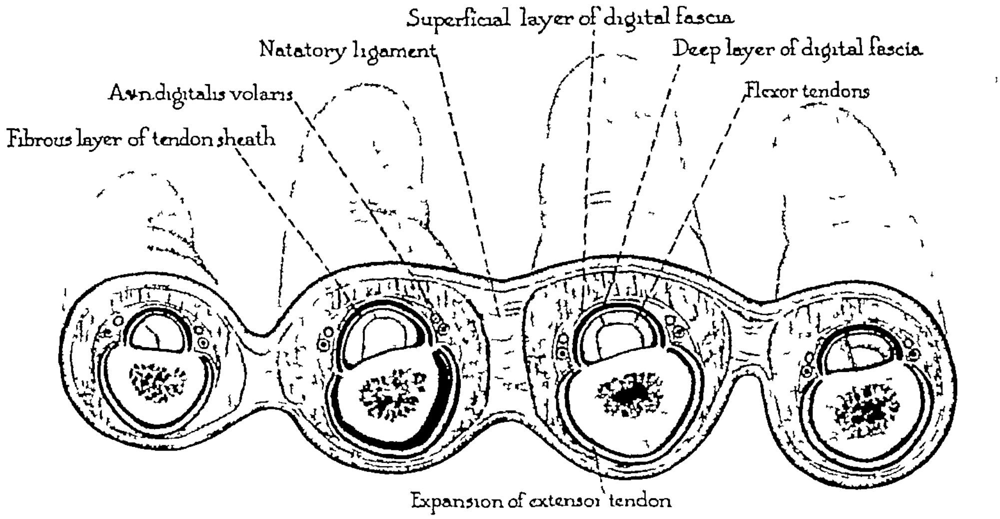


FIG 96

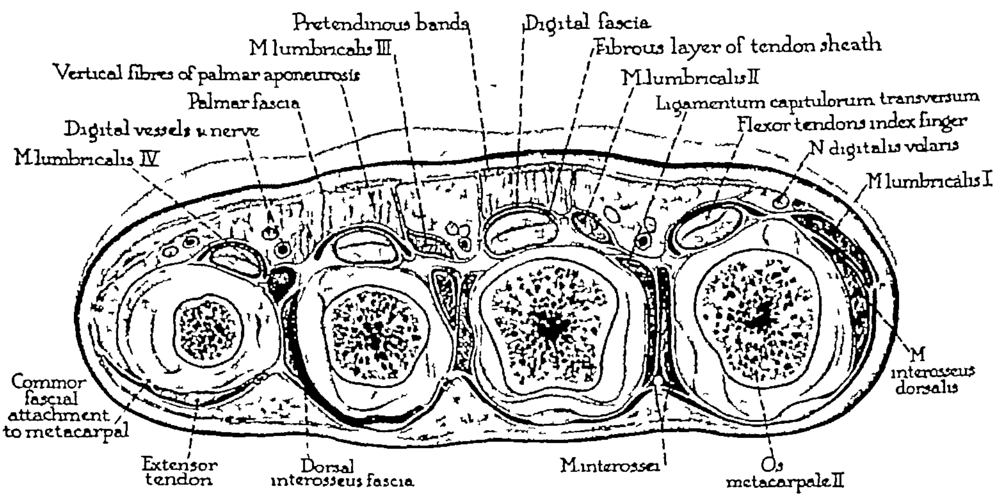


FIG 97

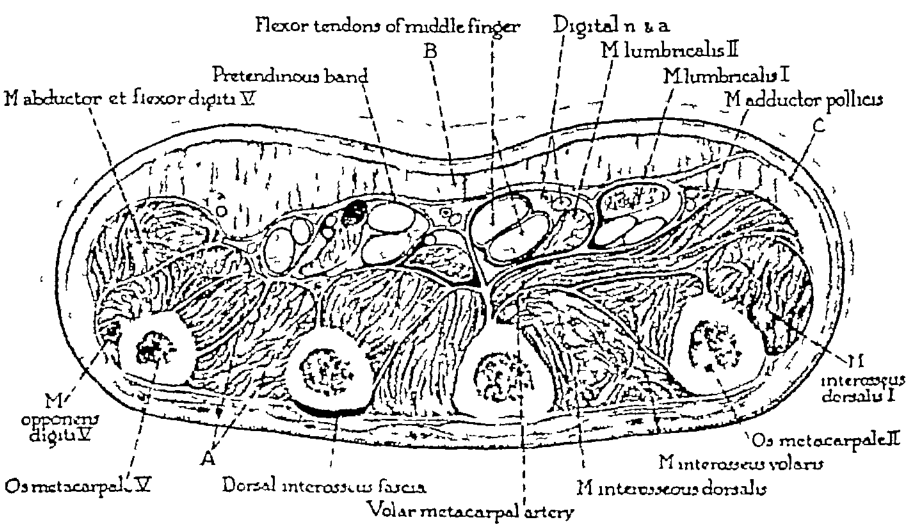


FIG 98

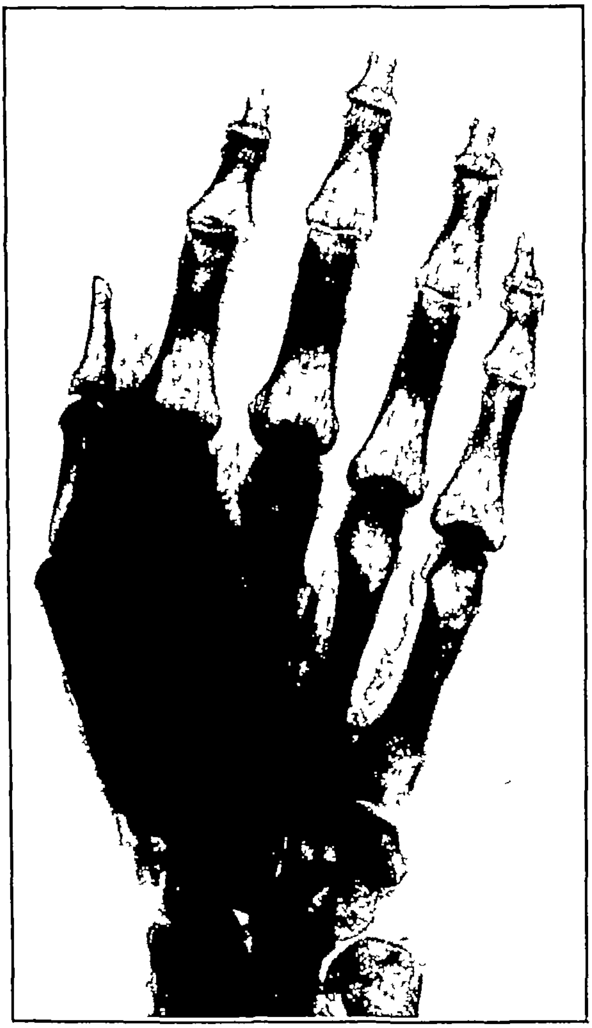


FIG 99 —Roentgenogram of experimental hand No 4, in which injection was made into the metacarpo-phalangeal joint of the index finger The injection mass obscures the whole radial one-half of the hand and the first interosseous space and has extended proximally as far as the wrist-joint

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LEGENDS FOR FIGS 95 TO 98

FIGS 95 to 98 —Cross-sections of experimental hand No 5 In Fig 95 the injection is seen to lie in the subaponeurotic or subtendinous space of the finger It has not extended about the finger, but is halted by the attachments of the tendon along the sides of the phalanx The same distribution is seen in Fig 96 taken just distal to the metacarpo-phalangeal joints In Fig 97, taken through the metacarpo-phalangeal joints, the injection mass is seen to have followed the extensor tendon and tendon of the dorsal interosseus muscle volarwards between the fourth and fifth metacarpal bones, while some of it has gained entrance to the fascia about the lumbrical muscle In Fig 98 the infiltration about the lumbrical muscle is seen to have extended into the palm

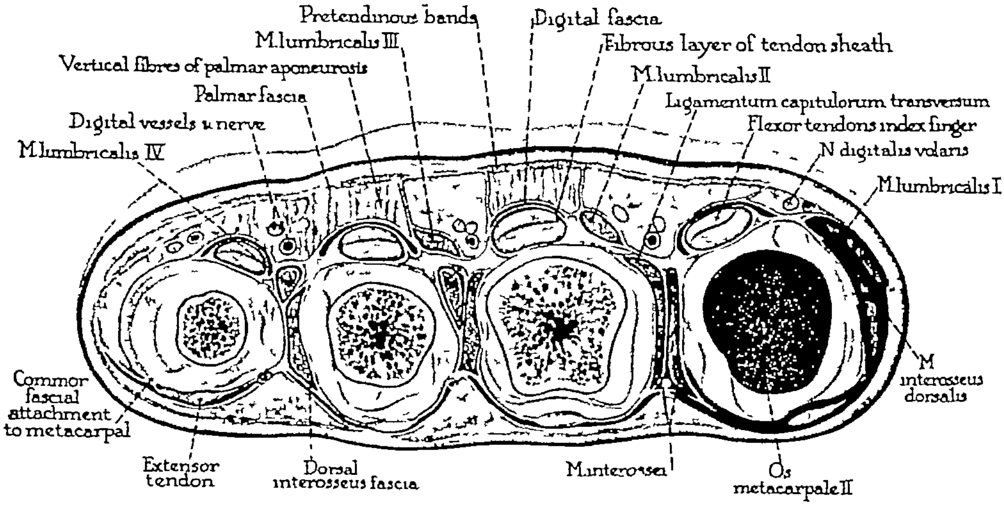


FIG 100

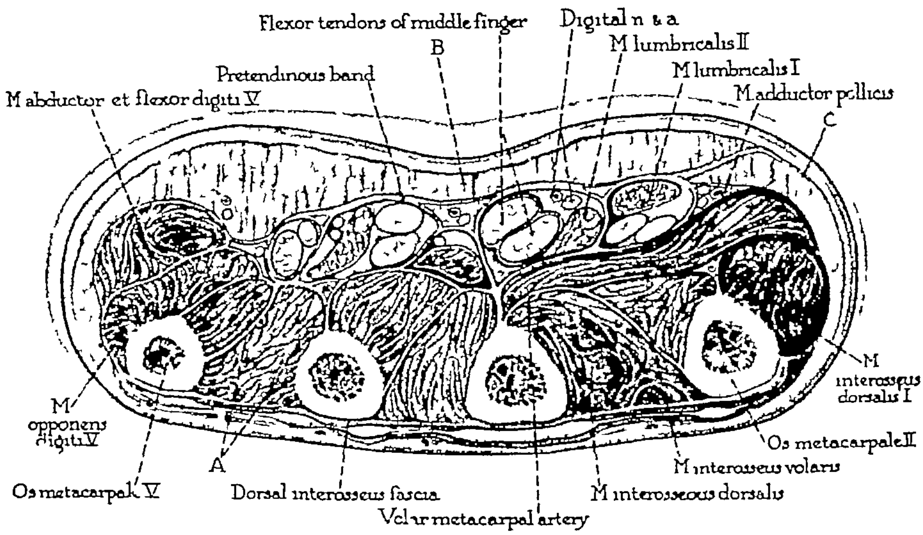


FIG 101

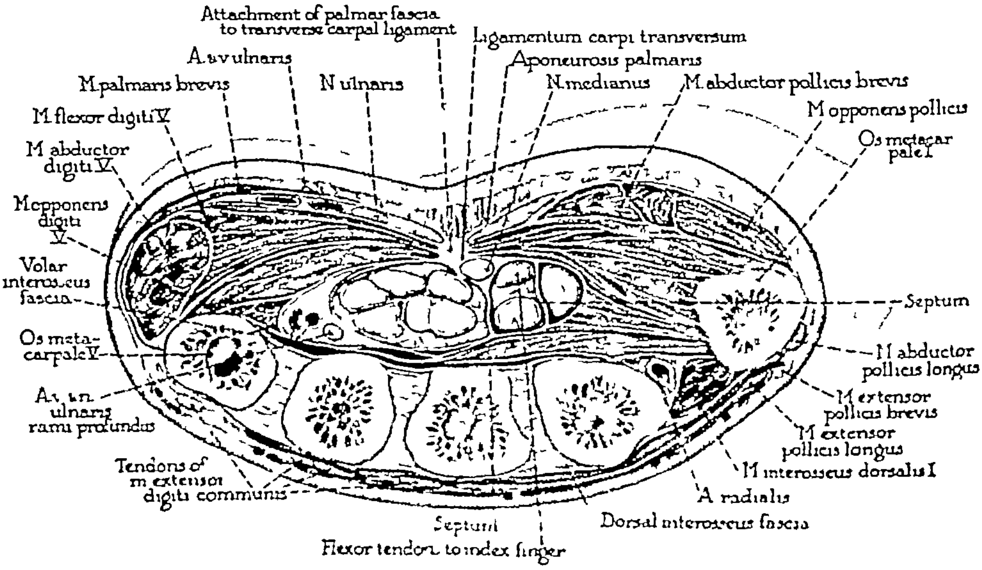


FIG 102

Injection of the gelatin-barium mixture beneath the extensor tendons resulted in one case in actual injection of a lumbrical muscle and extension within the substance of the muscle into the palm Clinically this is a common method of extension (Figs 97 and 98)

In one experiment in which the needle was forced through the lateral surface of the second metacarpo-phalangeal joint into the substance of the first interosseous muscle, the gelatin mass besides involving an extensive area over the dorsum, found its way palmarward and into the thenar space (Figs 99 to 102) This extension has been observed clinically

CLINICAL STUDY

While it is true that no two cases are ever exactly similar in any disease, there are so many things in common in mouth-bite infections that a fairly typical clinical picture can be drawn For sake of clarity we wish to present such a picture before noting the variations

The patient, a young man, presents himself to a physician with a lacerated wound on the dorsum of the hand over one of the metacarpo-phalangeal joints (Fig 103) The manner in which the wound has been received is

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LEGENDS FOR FIGS 100 TO 102

FIGS 100 to 102 —Cross-sections of experimental hand No 4 taken (Fig 100) through the region of the metacarpo-phalangeal joints, (Fig 101) through the middle of the metacarpus, and (Fig 102) through the bases of the metacarpals, reveal a widespread infiltration Thus in Fig 100 the joint space is seen to be filled with the mass, while external to the joint the barium lies both in the subaponeurotic and subfascial compartments on the dorsum and has extended around the radial border of the hand between and about the first dorsal interosseous and first lumbrical muscles In Fig 101 there is seen a more extensive infiltration on the dorsum in both the subfascial and subaponeurotic spaces, with involvement of the second dorsal interosseus muscle On the radial side of the hand the injection mass is seen to have followed volarwards about the interosseus and adductor pollicis muscles and lies in the floor of the thenar space Fig 102, taken farther proximally shows the still present extensive subaponeurotic and subfascial infiltration

frequently not disclosed and the possibility that the wound is due to a tooth injury therefore may not occur to the physician. After the wound is cleansed and the edges of the skin trimmed away, surgical closure is often made, and it may be thought wise to suture a divided tendon and close the joint cavity

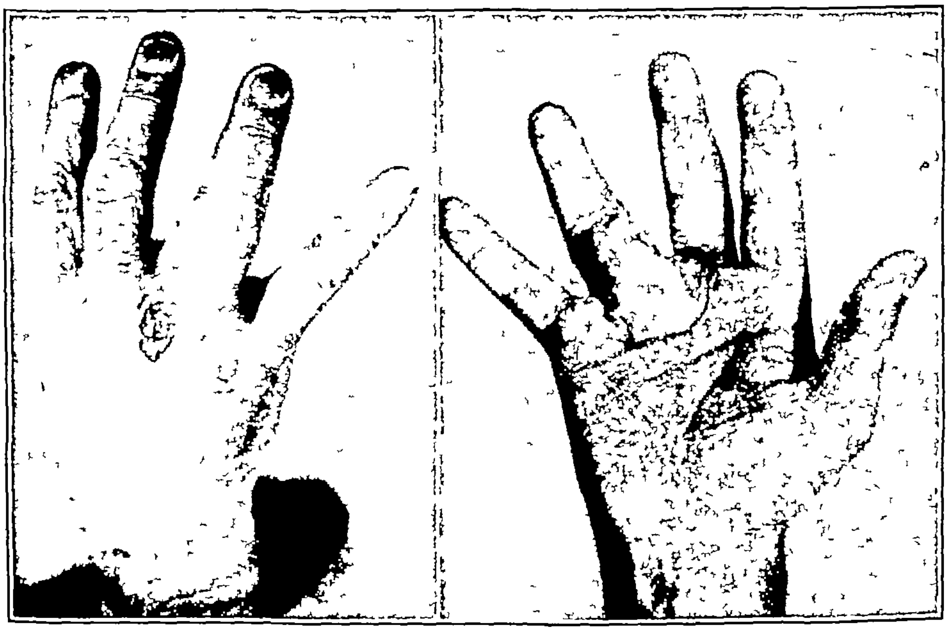


FIG 103 —(Case No 1573, Passavant Memorial Hospital) Photograph of *the right hand of a policeman who was bitten by a prisoner on January 12, 1930* Antiseptics were applied by a physician and wound packed with gauze Three days later, January 15, intense pain and swelling developed and the patient was sent to the hospital The original wound was enlarged and an incision made into the space between the fourth and fifth metacarpals Much foul pus evacuated January 22, a lumbrical space involvement was drained in the palm January 29, incision on radial side of proximal phalanx was made Smears and cultures showed Staphylococcus aureus, Bacillus mucosus capsulatus and Streptococci *salivarius Discharged from hospital February 22, drainage persisted* for about two weeks after discharge

Twenty-four or forty-eight hours later the patient again presents himself complaining of severe pain[1] in the hand The hand is then found to be considerably swollen A lymphangitis may be present at this time, though it is by no means constant. The constitutional

[1] Flick has not found pain a prominent symptom, while in our cases pain has often been quite severe

symptoms are not especially marked, but there is a moderate fever and a mild leukocytosis. The sutures, if any, are removed and hot wet packs applied to the hand, forearm and arm

The pain subsides, but the swelling and fever persist and after several days it becomes apparent that drainage is inadequate and that lateral and proximal extension has taken place By this time the secretion from the wound is moderately profuse and usually of a very

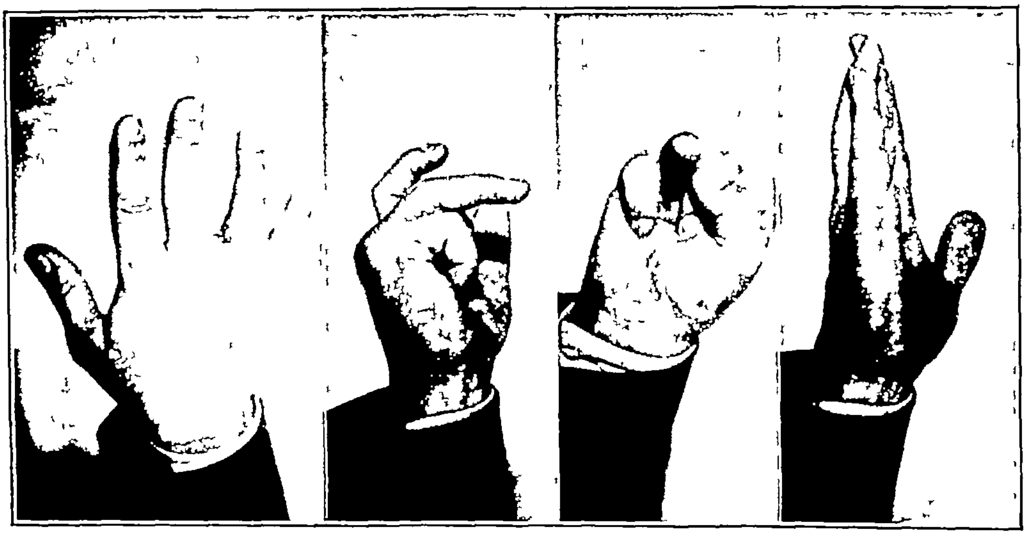


FIG 104 —Same patient as Fig 103 Photographs made May 15, 1930, four months after injury Wound and incisions entirely healed and motion being developed in ring finger

disagreeable odor, if the true nature of the infection has not been disclosed it is now suspected The original wound is opened more widely and found to communicate with the joint cavity. A considerable amount of grayish-brown fluid pus, exceedingly malodorous, is released Similar pus is found in the soft tissues at either side of the affected joint and beneath the extensor tendon Smears and cultures made from the pus show many organisms, among which may be the fusiform-spirillum combination of Vincent (Fig 106). Drain-

age of the wound leads to a fall in temperature and an immediate though temporary improvement.

Soon, however, there appears an induration in the palm, either over a lumbrical canal or over one of the larger fascial spaces, *i e*, the middle palmar or, very rarely, the thenar space These extensions require drainage, and at operation it is noted that with pressure on the dorsal and volar surfaces of the metacarpo-phalangeal joint purulent material can be expressed from the palmar incisions At the same time or later the proximal phalanx of the affected finger also shows swelling and signs of exudate The finger becomes swollen and indurated, painful on extension, and moderately tender The tenderness is most marked over the sides of the finger and over the metacarpo-phalangeal joint There is slight or no pain over the two distal phalanges and no local pain over the course of the tendon sheath The sides of the finger are incised, and more of the purulent exudate is released. The fibrous tendon sheath is seen to be intact though evidently inflamed, but the impression gained is that there is no pus within the sheath and it is not opened From now on improvement takes place The exuberant, edematous, weak looking granulations become more red and solid The discharge becomes progressively less, the odor disappears and after several weeks or a month or more the wounds finally heal, leaving a stiffened finger

At irregular intervals following closure of the wound "flare-ups" occur These consist of acute inflammatory reactions either on the dorsum of the hand under the original site of injury, or in the palm These areas are incised and the inflammation subsides promptly under hot moist packs Cultures from these foci may show fusiform bacilli; staphylococci and other organisms are usually present This "lighting-up" may be repeated several times before final cessation, and may occur as

late as twelve months after the original injury In some instances bone and joint involvement may have led to amputation early in the process

DISCUSSION OF CLINICAL COURSE

In our series of 16 cases of injuries by teeth there were 15 males and 1 female, a ratio such as we should expect from the nature of the injury All but 2 patients were young adults, from eighteen to thirty-eight years of age, 2 patients were fifty-one and fifty-four years of age respectively In 12 instances the right hand was affected, in 4 the left hand In all but 4 instances the injury was due to the patient striking another individual on the mouth and traumatizing the hand against a tooth. In 2 cases the patient was actually bitten, in 1 case on the right index finger in the other on the left thumb, in each instance by a woman In 1 instance the patient claimed to have injured himself with a tooth brush, a story which he maintained up to eighteen months after the original infection Either the story was true or the patient realized the importance of disclosing at least the nature of the source of the infection in a non-committal manner In another case the patient cut his right hand on a porcelain faucet and sucked the bleeding wound

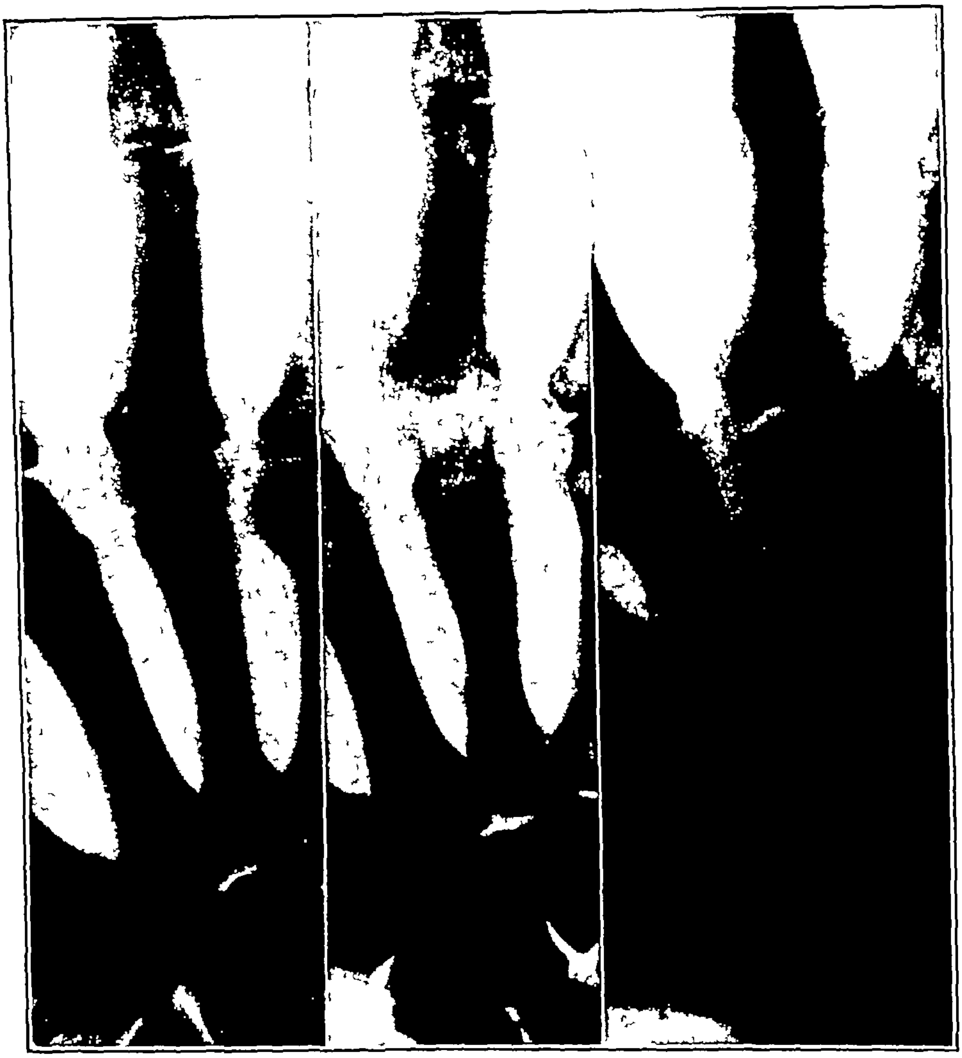
Falsification regarding the nature of the original injury is not at all infrequent and may lead to disastrous end-results following closure of a supposedly clean wound Self-treatment is also not infrequent following the wound, the patient presenting himself for treatment only after infection has started

The infectious process may become manifest in as short a time as three hours following injury, and while usually two to three days elapse between the time of reception of the wound and onset of symptoms, occasionally a week or ten days may intervene. The more severe infections occur earlier as a rule

Extension of infection from the original focus in cases of typical injury over the metacarpo-phalangeal joint takes place at first in a concentric manner under the dorsal fascia or aponeurosis onto the dorsum of the hand and into the web spaces between the heads of the metacarpal bones These areas call for early drainage Somewhat later (ten to fourteen days) an extension may occur into the palm, either along the lumbrical muscles or about the digital nerves and vessels. The palmar involvement may be present in a lumbrical canal, or in one of the major fascial spaces of the hand Extension about the proximal phalanges of the fingers is likely to be of later occurrence than extension into the palm This is manifested by a general swelling of the proximal phalanx associated with marked pain and tenderness This pain is referred mainly to the metacarpo-phalangeal joint and the tenderness is most marked on the volar surface of the proximal phalanx This may lead to a diagnosis of tenosynovitis and occasion the unnecessary opening of a tendon sheath The dense fibrous tendon sheath and the deep digital fascia tend to protect the synovial sheath of the flexor tendons from involvement

Involvement of the bones which is present in well over two-thirds of the cases is most often primary, from inoculation directly into the metacarpo-phalangeal joint cavity, or from actual injury to the bone The joint involvement is usually manifested at once, as a severe suppurative arthritis This may result in actual destruction of the bones entering into the formation of the joint, though it has been our experience that with adequate drainage the arthritis may subside without complete destruction of the joint Infection of the bone itself, except by direct involvement from the joint cavity is usually a periostitis and if treated conservatively tends to subside.

A word of warning may be in place with regard to the interpretation of roentgenograms in these cases Not infrequently the surgeon or radiologist forgets how



A B C

Fig 105 —Roentgenograms of hand of same patient as illustrated in Figs 103 and 104 *A*, Destructive process visible in the fourth metacarpo-phalangeal joint, February 4, 1930 *B*, Roentgenogram made February 25, 1930, rarefaction of bone in the joint and periosteal proliferation are evident *C*, Roentgenogram made April 12, 1930 The rarefaction is diminishing, the destruction is less and improvement is taking place

quickly atrophy of disuse makes itself apparent by the absorption of lime salts from the bones of the hand. A diagnosis of osteomyelitis and bone destruction has been made on several occasions when slight infection

was present and the process of rarefaction was mistaken for infection (Fig. 105).

Late manifestations and recurrences of the infection are not at all rare in our experience These may occur during the first two or three months following injury or as in 1 of our cases not for a year after the original injury These recrudescences or flare-ups often follow trauma, are not infrequently found in the palm, and are usually not as severe as the original infection.



FIG 106 —Smear from human bite infection Many pus cells among which are spirilla and fusiform organisms

BACTERIOLOGICAL FINDINGS.

The infecting organisms which are introduced into the wounds are numerous and varied, however, not all of the habitants of the mouth are pathogenic and many do not survive outside their normal habitat, and many which do survive are probably not recognized by the usual clinical laboratory methods of culture It is apparent to anyone who has studied these infections

that the process is due to or at least associated with a symbiosis of various organisms, prominent among which are the various staphylococci, streptococci, and the spirochetal-fusiform groups of organisms with which the name of Vincent or Plaut-Vincent is usually associated (Fig 106) Not every case of human bite infection is due to the fusiform-spirochetal symbiosis, nor is it always possible to demonstrate the organisms in the presence of a typical infection However, dark-field illumination on absolutely fresh material and careful anaerobic cultures observed over a period of a week or ten days will yield much information It should be kept in mind that the spirochete of syphilis may be inoculated by a human bite, an occurrence which Owen has noted three times.

PROGNOSIS

Patients are frequently incapacitated for a considerable period following the injury, the time of disability in most instances can be reckoned in weeks and months instead of days Bates, who has had a large experience in the treatment of these cases, believes that with heat cautery excision this period can be shortened considerably and that hospitalization can be avoided in practically all cases Owen, however, with an equally large experience states that after a trial of all methods of treatment results are no better than they were twenty years ago Certainly after infection has once started the process is long and requires constant supervision.

TREATMENT.

The principles of treatment of bite infections are not different from those of other infected wounds, but the factors emphasized above—the complicated anatomical arrangement of the tissues of the dorsum of the hand and fingers, which predispose to the extension of

infection rather than to limitation of it, the presence of a mixed infection with organisms of relatively high virulence, and the relatively low resistance of fibrous connective tissue and cartilage to infectious processes in general—tend to prolong unduly the course of such infections, to predispose to the destruction of fascia and tendons and to the involvement of bones and joints, and, as a result, to produce eventually a more or less extensive impairment of function

Although we have not had the opportunity of treating a single case primarily, or immediately after the injury, we believe, as a result of our observations, that the most important factors in the primary treatment are careful cleansing of the wound without any attempt at wound closure, hospitalization and immobilization of the part, and either the immediate application of warm, wet, sterile dressings, or institution of Carrel-Dakin treatment, with the utmost care to prevent the addition of further infection.

Cleansing of the wound, we believe, should be done gently, and with soap and water rather than with powerful chemical solutions which are quite as likely to kill living cells as to kill bacteria which have been introduced into the tissues Obviously damaged tissue should be cut away, and the wound left widely open without any packing or gauze which might interfere with drainage Bates, who has had considerable experience in treating these injuries, advises very thorough actual cautery excision, even to removal of tendon Certainly in view of the long disability which often follows the injury and the total or partial ankylosis of joints which often occurs, radicalism in excision would seem to offer the best chances of speedy recovery

The continuous application of warm, wet, sterile dressings produces an active hyperemia and mobilizes the forces that overcome infection. It should not be

continued, however, long enough to produce edema of the part and maceration of the superficial tissues Intermittent soaking in warm, sterile solutions, or the use of Dakin's solution, should be substituted for the continuous warm, wet dressing before the hand becomes congested—usually at the end of three or four days

Extension of infection should be carefully watched for The surgeon should remember that extension of infection is likely to take place (1) lateralward in the soft, superficial subcutaneous tissue of the dorsum of the hand, (2) under the digital fascia of the proximal phalanx, and so around the finger, (3) more deeply, distalward along the proximal phalanx under the extensor tendon, with subsequent periostitis and osteomyelitis, (4) on the dorsum of the hand, as distinguished from the finger, under the extensor tendons and the fibrous tissue which unites them to form the dorsal aponeurotic layer, (5) along the lumbrical canal into the palm and thence into the middle palmar or thenar space, (6) less commonly, and usually at the end of ten or twelve days, through the joint into the palm, under the volar interosseous fascia and thence into the middle palmar or thenar space, and (7) by erosion of the fibrous flexor tendon sheath into the synovial sheath

Successful treatment requires the recognition of extension of infection to these different sites, and incision before the accumulation of pus under pressure causes extensive necrosis of tissue Incisions for drainage, needless to say, must be made with due regard for important anatomical structures If infection extends through the joint into the palm, the affected space in the palm should be drained, but through-and-through drainage of the hand, we believe, is never indicated.

"Scraping of the bone" and curettage of the joint cavity, as has been emphasized above, is likely to do more

harm than good. If the infection of the soft tissues, fascial spaces, and the affected joint is adequately drained, bone involvement tends to clear up spontaneously. We have seen sequestrum formation in only one case, even though roentgenograms have shown evidence of extensive periostitis and grating sounds on movement have given definite evidence of destruction of joint cartilage. Even though joint cartilage is destroyed, bony ankylosis does not necessarily take place, and mobility may still be preserved if efforts are made to prevent fibrous ankylosis by the institution of early movement

Involvement of the flexor tendon sheath, as has been pointed out is unusual It occurs as a late result of extension of the infectious process through the metacarpo-phalangeal joint into the palm In one case this palmar extension was not recognized until erosion of the fibrous sheath and invasion of the synovial sheath had occurred In the other case in which involvement of the flexor tendon sheath occurred a rubber tube had been passed from the palmar surface to the dorsum of the hand between the third and fourth metacarpal bones Not only was the fibrous tendon sheath eroded with a resulting tendon sheath infection, but the flexor tendons of the ring finger were divided by pressure erosion of the tube combined with the destructive action of the infectious process.

Although we have not seen a case in which a syphilitic infection was transmitted to the injured hand, this possibility, as is emphasized by the 3 cases reported by Owen, should not be forgotten In 1 case in which the Wassermann reaction four weeks after the injury was negative, neosalvarsan was given intravenously but apparently without an helpful effect, however, its use in the treatment of such infections as show themselves to be spirochetal in nature may be of some value

SUMMARY

Bite and other infections about the metacarpo-phalangeal joint are frequently prolonged in their course and difficult to clear up because the infection is usually introduced deeply into the tissues through a comparatively small wound, because of the character of the infection, because of the anatomical arrangement of the structures involved, and because of the relatively low resistance of fascia, tendon, cartilage and bone to a mixed infection such as is caused by the organisms present in the mouth

Such infections when introduced into the tissues of the dorsum of the hand—the most common site of inoculation—tend to spread to definite areas, and this extension depends particularly upon the exact site and depth of the primary inoculation and upon the ease or difficulty with which the infectious material can escape to the surface

In the treatment of such infections an exact knowledge of the sites to which infection tends to spread is of importance These are in order of frequency, the subcutaneous space of the dorsum of the hand, the subfascial space of the dorsum of the proximal phalanx, the subaponeurotic spaces of hand and fingers which lie directly over metacarpal bones and proximal phalanges, the metacarpo-phalangeal joint, the fascial spaces of the palm and the flexor tendon sheaths If these sites are kept in mind, extension of infection can be recognized early and accumulations of pus drained before extensive necrosis of tissue has taken place.

Unless such infections are drained early and adequately, bone, joint, and tendon involvement are certain to occur and to lead to extensive impairment of function.

CHAPTER XIV

GANGRENOUS INFECTIONS.

Streptococcic, Symbiotic and Gas Gangrene

GANGRENOUS infections as they appear in the hand and arm present some of the gravest questions confronting the surgeon In many cases the etiology is uncertain, the diagnosis as to type and extent difficult to make, the proper method of treatment still unestablished, and the prognosis uncertain.

For clarity of consideration we may divide the groups into local and spreading. In the local group will be considered the localized processes, generally involving digits, in which there is a destruction of tissue more or less *en masse* In the spreading groups is included the so-called phlegmonous erysipelas and gas bacillus infections due to virulent extending infections characterized by subcutaneous destruction of connective tissue and muscle followed in some cases by gangrene of areas of the skin or the extremity

The etiology of the infective type, if we exclude the gas bacillus infections, is still poorly understood and although certain facts stand out prominently in many cases yet there is still much of theory in our explanation of these cases Much speculation based upon the findings in individual cases has been indulged in without positive conclusions Some have emphasized the rôle of the fusiform bacilli, spirochetes and other organisms found in Vincent's angina and similar infections, others have attributed to symbiosis the chief influence in these gangrenous infections In the first edition of this book attention was given symbiosis in this condition, and while

little of positive nature has been added it has assumed a greater importance due to studies made in gangrenous infections of other parts of the body, especially those in the abdominal wall sequential to infected wounds such as appendicitis Some studies of rapidly spreading gangrene of the breasts and upper extremity have corroborated these findings The difficulty arises from the fact that one is never certain whether all the organisms were present from the beginning or some followed secondarily after the process was established by one We have many instances in which a streptococcus, especially the hemolytic type, has been found early and later the staphylococcus has appeared in the cultures, while many of course show both in the first culture This has commonly been our experience in our cases of phlegmonous erysipelas and in the localized gangrenes of the digits We have at times, however, found only the staphylococcus although the clinical history and early appearance was that of a typical streptococcic infection Pfanner in 5 of his cases of phlegmonous erysipelas (necrotizing erysipelas, Pfanner) found only the streptococcus Meleney, who has made extensive studies of this subject, describes a type of gangrene essentially superficial in nature involving the skin, not preceded by the clinical picture of erysipelas but of rapid onset originating in all cases from the hemolytic streptococcus. Of 17 such cases, 8 occurred in the upper extremity. The consensus of opinion is that in certain cases at least the synergistic action of the streptococcus and the staphylococcus is the dominant factor. It is certain that the combination produces at times a toxin or ferment, not the product of either alone Meleney suggests that the lytic product which causes gangrene is made by the action of one organism on some intermediate product of metabolism produced by the other Whatever the facts may be, clinically we generally see the

pictures we have learned to associate with streptococcic infection precede the gangrene and generally we soon find both the streptococcus and the staphylococcus on culture. Other bacteria such as the pyococcus may be found.

We find another group of gangrenous lesions, especially following injuries from bites or blows on the teeth, in which the organisms associated with Vincent's angina are found both at the inception of the trouble and after many weeks in the unhealed lesion Drs Mason and Koch have considered this subject in an exhaustive contribution from our clinic. After a study of the recorded cases, an exhaustive anatomical investigation, and a review of the histories of the patients they have observed, it would seem that there are other factors just as important or more so than the infection with the Vincent's organisms, but that they in combination with others may produce gangrene seems proven. The bacteriology of Vincent's angina is not definitely known, but many think it to be a symbiosis between a fusiform bacterium and a spirillum while others believe it is a morphologic variation of the same organism Streptococci predominate in cultures from the mouth followed by fusiform bacteria, then spirilla, and last of all the spirochetes Probably here again the gangrene is due to a synergistic action or one type of organism prepares the field for the lytic action of others

LOCALIZED GANGRENE

The ordinary types due to age, thrombosis, and trophic nerve injury need not be considered here, we should, however, not forget that incident to the treatment of infections we still see carbolic acid gangrene due to the ill-advised application of carbolic acid dressings either in the form of wet dressings or carbolized medicaments, chiefly carbolized vaseline Fortunately this has not

been seen so frequently of late years, but it is still met with often enough to justify an emphatic protest against its use in any form When confronted with a gangrene *en masse* of a digit the surgeon should always inquire whether carbolic acid has been used

Gangrene of a part of a digit or a part of the hand, especially about the metacarpo-phalangeal joint, due to infection is seen not infrequently The acuter form seen in our clinic has generally attacked the distal phalanx. There may or may not be a history of injury. Hultgen reported what he believed to be the first instance of "gangrenous perionychia" due to the symbiosis of fusiform bacillus and the Spirochæta denticola His patient was a girl, aged seven years, who infected her left index finger by biting her nails Smears from the girl's teeth showed the same organism On the other hand, in two cases of rapidly-spreading gangrene originating about the nail seen by myself careful cultural examination of smears from the surface disclosed only the staphylococcus although the clinical history and appearance of the hand and arm was that of a streptococcus lymphangitis at its inception

In the few cases of distal digital gangrene not due to bites that I have seen the clinical history has been as follows· There may or may not be a history of injury. The infection has generally had its origin at the side of the nail After a few hours of intense pain the red lines of a typical lymphangitis appear running up the arm Within twenty-four to forty-eight hours a beginning gangrene is noted at the site of the original pain This spreads rapidly and within another twenty-four hours the gangrenous area may be ½ inch or more in diameter Where a primary incision had been made the process seemed to spread more rapidly From this time the involved area may increase or remain stationary Meanwhile the lines of lymphangitis become more marked

The patient complains of great pain, shows the prostration and marked symptoms of grave toxemia.

Prognosis —Under conservative treatment the gangrene generally ceases to extend and the ultimate loss of tissue is less than would appear probable early in the course If it extends, however, and involves the bone and joints, amputation may be indicated Exceptionally after a few days the tendons may become involved with typical suppurative tenosynovitis and demand treatment appropriate to this complication

Treatment —It is apparently wiser in these cases to use the conservative measures I have emphasized in the treatment of lymphangitis Absolute rest of the patient and the infected hand and arm, voluminous moist dressings extending up to the shoulder kept warm by the introduction of hot boric solution at frequent intervals through open channels in the dressing, the whole dressing being enveloped in some impervious covering such as rubber or oiled cloth An electric light, heater, or electric pad is used to maintain the heat Large amounts of fluid, 3000 to 5000 cc , are given every twenty-four hours, and appropriate sedatives if necessary The hand should not be dressed oftener than twice daily In the treatment of the gangrenous area extreme conservatism should be exercised, any incision apparently does more harm than good unless the gangrene is so massive that amputation is advisable If this is done it is probably wiser to use the cautery knife and leave the wound opened widely In my experience this will seldom be necessary if the proper conservative measures are carried out In one case of mine a bacteriophage was used locally although I have doubt whether or not this was of any value It did no harm however After a few days local subepidermal pus pockets may be opened, necrotic epidermis and loose gangrenous tissue removed.

BITE GANGRENE

Gangrene may follow bites or cuts by the teeth commonly following fights in which the knuckle is injured. The gangrene here is generally not so fulminating The process is more chronic, the gangrene following some days after the injury in a frankly infected wound It is seldom *en masse*. These injuries and the chronic gangrenous wounds following are peculiar to themselves and have been considered in the previous chapter

SPREADING GANGRENOUS STREPTOCOCCIC AND SYMBIOTIC INFECTIONS

The etiology of this type has already been considered The pathology is that of a rapidly spreading gangrenous infection, more commonly involving the forearm or arm To it the descriptive term "gangrenous or phlegmonous erysipelas" has been aptly applied. While at times the skin may be the site of the major gangrene, more commonly the skin remains more or less intact and it is the subcutaneous connective tissue that is destroyed The infection commonly originates in some small injury. Within twenty-four to forty-eight hours the arm is markedly swollen, the skin violently inflamed, glossy, red, hot, and tender In the first few hours it may present the typical picture of a rapidly spreading erysipelas with pitting edema, but this clinical picture is soon lost Any typical advancing edge on the skin disappears, the uniform violent red color is present without any line of demarcation and the pitting edema gives place to a brawny hardness of the greatly swollen arm Blisters and bullæ appears on the skin, first filled with clear yellow serum, later becoming dark giving the appearance of skin blistered by heat The patient presents the picture of an intense toxemia with high fever, rapid pulse, and marked prostration The gravity of the

infection may be evidenced by delirium In some instances, localized areas of gangrene may appear on the skin or these may be extensive If localized, the process may subside with the separation of the slough and heal after local discharge of pus and subcutaneous necrotic tissue or ulcer formation. More commonly, however, the skin remains more or less intact Massive destruction of the subcutaneous tissue occurs, the whole forearm or arm becoming a bog of subcutaneous necrotic tissue and pus within three to four days Openings may appear through small areas of necrotic skin and massive sloughs of connective tissue be extruded with slow recovery or not infrequently with death supervening within a few days In the more severe cases the toxemia may be so great that the fever is not high, but the prostration profound and pulse extremely rapid In the more chronic type and even in the severe ones metastatic streptococcic erysipelas or abscesses may appear

A fatal case of phlegmonous erysipelas came under my care in which the patient made a primary recovery, but died after four weeks from a pneumonia, probably directly dependent upon the primary infection Indeed, these serious cases of infection frequently come to a fatal issue because of some intercurrent complication, and this should always be looked for and guarded against A brief résumé of the case will emphasize the clinical picture.

Case VI —Mr J R D (Fig 107), an employé of the customs house, bruised the thumb of his right hand in getting off a street car As he expressed it, he thought that he had dislocated the thumb There was some primary swelling At the end of the third day there was a considerable increase of the swelling, so that the whole thenar area was involved, and the forearm also began to increase in size He now consulted Dr J J Cole, with whom I saw the patient in consultation The swelling of the thenar area was so great as to suggest the ballooning out seen in the abscess of the thenar space The swelling was distinctly an edema, however, there being no hardness present It was treated by hot boric dres-

sings Within a few hours the whole arm was swollen and edematous, as much upon its flexor as its dorsal surface, although the dorsum showed some redness which was not present on the flexor surface Deep tenderness could be elicited on both surfaces, especially over the radial side By the end of the third day the swelling of the arm had subsided to a considerable extent, and the swelling of the flexor surface of the forearm was distinctly less The dorsum, however, was still swollen, having the appearance and giving the same sense of hardness on palpation as noted in erysipelas. Incisions made upon the dorsum showed that the subcutaneous connective tissue was necrotic *en masse* and could be removed with the forceps The whole dorsum of the forearm was undermined

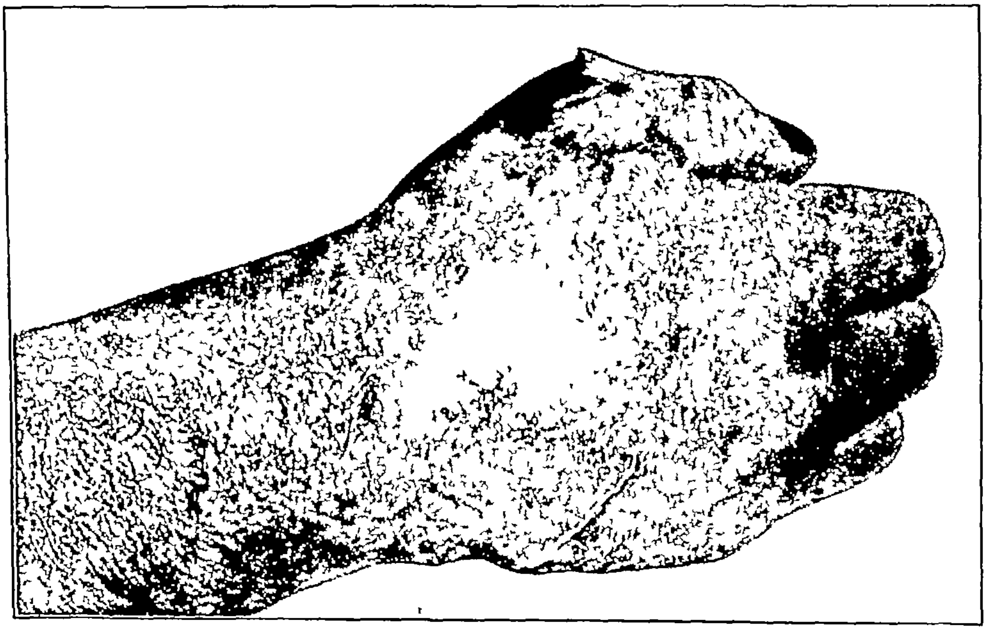


FIG 107 —Photograph of the hand of a patient with a deep lymphangitis (phlegmonous erysipelas) (See Case VI)

Several incisions were made which drained satisfactorily Owing to the large flaps of skin left without blood supply, in which the vitality was impaired by the infection, some areas of this also sloughed. As the process subsided the thrombosed superficial veins could be seen on the surface of the deep fascia The patient made a rapid primary recovery, so that he left the hospital at the end of eight days The local process, however, had not entirely healed Some slight toxemia was present, from which the patient was slowly recovering, when he was suddenly overtaken by a pneumonia at the end of four weeks, and died after three days A culture taken from a bleb which had formed upon the skin showed a staphylococcus infection In the subcutaneous pus, however, a pure culture

of Streptococcus pyogenes was found, and I believe that to have been the source of the infection Unfortunately, no postmortem could be secured

Incidentally, this finding of the staphylococcus under the epidermis, when the real cause was a streptococcus, emphasizes the error, which is common, of mistaking the local subepidermal infection for the primary cause when it may be really secondary.

TREATMENT —In the early hours or first two or three days of the infection extreme conservatism must be exercised It is evident that no incision can be expected to limit the infection. Therefore, at the inception of the process we must depend upon the measures we have advocated in the treatment of lymphangitis—complete immobilization of the arm by voluminous moist hot dressings extending up to and over the shoulder, kept moist and warm by the methods we have described in the chapter on Lymphangitis, and 3000 to 5000 cc of fluid daily by mouth or rectum and, when this is not absorbed, by intravenous injection. Subcutaneous infiltration of normal salt is liable to be followed by metastatic infection at the site of the injection and therefore should not be used Liquid, easily digested foods, sedatives for rest, and other supportive measures are important Blood transfusions may be of value particularly later in the course. The repeated intravenous injection of dextrose in Ringer's solution or otherwise is most helpful since the absorption of food by the stomach is impaired and the administration of food and dextrose by the rectum is unsatisfactory

While in the first day or two incisions are harmful the time soon arrives when the evacuation of necrotic matter is necessary The calmest judgment is necessary as to when this time has arrived This is frequently about the third day when the brawny hardness gives some slight evidence of fluctuation The incisions

should be made with the cautery knife and should be extensive, generally several inches in length, and may be multiple on the flexor and dorsal surfaces so as to give free drainage Sloughs of subcutaneous tissue, if detached, should be removed or, if partially detached, may be dissected out with the cautery knife It is evident that upon the arm where the whole area is involved we cannot dissect off the skin and subcutaneous tissue *en masse* as is advocated in similar infections on the abdomen and on the breast

The after-treatment requires vigilance—prompt evacuation of new necrotic areas, large amount of fluid intake, blood transfusions, and dextrose intravenously Locally the removal of undetached sloughs may be hastened by the instillation of Dakin's solution every two hours with the usual precautions to be certain the solution is of proper strength and the skin protected Secondary hemorrhage may occur from large veins and attendants should be warned to watch for this complication

GAS GANGRENE AND MALIGNANT EDEMA

Infective gangrene due to various anaerobic organisms producing gas and edema is sharply differentiated from the infective gangrene due to aerobic bacteria described above It has been described under many titles such as gas gangrene, phlegmonous gangrene, emphysematous gangrene, malignant edema, etc In 1853, Maisonneuve first described the disease and Pirogoff, eleven years later, again drew attention to it under the title of "acute gangrenous edema" Simonds, in 1915, collected reports of 175 cases of gas gangrene occurring in civil life due to the Bacillus perfringens. To the World War, however, with its frightfully lacerated wounds contaminated with dirt we owe our present conception of this disease

While the marked clinical evidences are due to the

presence of the various anaerobes there is strong evidence that the completed picture is not uncommonly produced by the synergistic action of both aerobes and anaerobes, some authors going so far as to say that without these the Bacillus perfringens and Bacillus œdematiens in pure culture are not strongly pathogenic From a bacteriological standpoint the subject still needs much study The statistics as to the types of organisms present are inaccurate since in many cases the investigators have been content after finding only the Bacillus perfringens and in other instances the discoverer of some organism or his students have found this present in a large proportion of cases because of their intensive study Pasteur believed the causative organism to be the vibrion septique Koch and Gaffky named this same organism the bacillus of malignant edema Welch and Nuttal in 1892 discovered the Bacillus perfringens Weinberg and Seguin isolated the Bacillus œdematiens and studied 91 patients suffering from gas gangrene In 24 cases the anaerobes were unaccompanied by aerobes, in 67 they were found in symbiosis with one or more aerobes In 37 cases there was but a single anaerobe and in 54 there were more than one

In their analysis of these cases they found anaerobes as follows. Bacillus perfringens in 70 cases (77 per cent), Bacillus œdematiens in 31 cases (34 per cent), Bacillus sporogenes in 25 cases (27 per cent), Bacillus fallax in 15 cases (16 5 per cent), Bacillus of malignant edema in 12 cases (13 per cent), Bacillus tetani in 9 cases (10 per cent), Bacillus histolyticus in 8 cases (9 per cent), Bacillus aerofœtidus in 5 cases (5 5 per cent) Bacillus putrificus in 2 cases (2 per cent), Bacillus bifermentans in 2 cases (2 per cent), Bacillus Ghon-Sachs II in 1 case (1 per cent), and Bacillus tertius in 1 case (1 per cent)

Miller in an analysis of 607 reported cases from civil life found that the great majority reported the Bacillus

perfringens as the only organism, showing the inadequacy of the average bacteriological studies.

It is to be hoped that in the future a complete study of all anaerobes and aerobes will be made so that serum therapy may be founded upon a more scientific basis since it is certain that in most cases a number of different organisms are present

Bearing in mind that aerobic bacteria are generally present in symbiosis it may be stated that the most common anaerobes found are Bacillus perfringens, vibrion septique, Bacillus œdematiens, and Bacillus sporogenes To these Weinberg and Sequin add the Bacillus fallax Of these the Bacillus perfringens is by far the most frequent

Vincent in a study of war wounds found the Bacillus perfringens in 82 per cent of the cases, vibrion septique in 10 per cent, the Bacillus œdematiens in 4 to 5 per cent

The varying clinical pictures and percentage of mortality are dependent, other factors being equal, upon the preponderance of one or more of these organisms. The Bacillus perfringens is less toxic but is characterized by the production of large amounts of gas The vibrion septique and Bacillus œdematiens produce less gas, are extremely toxic, and are characterized by the production of large amounts of edema, especially the latter, so that when these predominate the gas formation may be masked Gemmill believes that where the vibrion septique is present the disease is always fatal The Bacillus sporogenes is probably not toxic but is responsible for the putrid character of the wound

Bearing these facts in mind it is evident that three clinical types of gas gangrene may be seen (1) Preponderating gaseous (classic gaseous gangrene), (2) toxic, (3) mixed

Classic Gaseous Gangrene.—This is characterized by the following symptoms Abundant gas production,

considerable gaseous crepitation, often superficial, bronze tint on the skin, blebs, and in fatal cases septicemia often setting in a few hours before death Of this type of gaseous gangrene it is believed that the Bacillus perfringens and Bacillus of malignant edema, either singly or in symbiosis, are most often the causative agents Sometimes an extremely toxic organism like the Bacillus œdematiens may be associated with the other agents in this type of the disease

Toxic Gaseous Gangrene —This type differs from the classic in that progressive, spreading edema masks the infiltration of the tissues with gas and, together with general symptoms of intoxication, constitutes the most apparent outward sign of the infection. There is rarely septicemia, even in fatal cases So different is this type from the classic, that surgeons tend to associate it rather with streptococcic infections (white erysipelas) than with genuine gaseous infections It is thought that the Bacillus œdematiens is the causative agent of this form of the disease, although the Bacillus perfringens sometimes produces similar results

Mixed Gaseous Gangrene —This form includes cases which present not only the complex flora (Bacillus œdematiens and Bacillus perfringens) but also the leading symptoms of the two preceding varieties (classic and toxic) These symptoms are usually edema and gaseous crepitation

Pathology —The pathology is that of the formation of gas in the rapidly disintegrating muscles, the gas becoming evident as soon as it passes from the necrotic muscle to the intermuscular connective-tissue spaces In the more toxic types edema is predominant Later, if the blood supply has been impaired by the primary injury or by compression of edema or gas, massive gangrene of the part may appear The disease is chiefly one of the muscles and is most often seen when there

has been a primary injury of one or more of them It is rare to find all the muscle of a segment of a limb involved The muscles affected are, in the first instance, the wounded ones but if the pressure is not relieved it may spread to others Muscles contained in rigid compartments are especially prone to die if wounded

In an infected limb the muscles may be seen in several stages of destruction. (*a*) Normal purple-red contractile muscle which may or may not be infected as judged by cultural experiments (*b*) Dead, non-contractile, non-crepitant muscle which has a peculiar red color and is less translucent than normal muscle (*c*) Dead, non-contractile, crepitant muscle which has the same appearance as the last (*d*) Brown, black, or diffluent muscle (Muscle dead from the cutting of the blood supply is a purplish brown, and its naked-eye appearance quite different from (*b*) and (*c*))

McNee and Dunn have described the microscopic picture as follows There is first a separation of the muscle fibers from the surrounding interstitial tissue with a clear space between the fibers Later the sarcolemma disappears and the muscle fibers disintegrate and become gelatinous No bacteria are seen in the invading clear zone but are seen throughout the dead muscle Bull and Pritchett have demonstrated the presence of two toxins, one a hemolysin and the other a toxin causing edema and necrosis

Diagnosis —The gas gangrenes are most often seen in lacerated wounds resulting from explosive violence and compound fractures where muscles have been injured in such a manner that clothing or earth, especially that contaminated with animal excreta, has been driven into the deep tissue In such cases the surgeon should dress the wound two or three times or more daily to discover the earliest signs of the disease. Tenopyr suggests that where we fear such infection a portion of

the lacerated tissue removed at the primary treatment should be placed in a sterile test-tube and covered with melted agar If anaerobes are present, gas bubbles will be seen a few hours after incubation. It is also wise to take frequent roentgen-ray pictures, every six to eight hours, to detect the presence of gas in the tissue. Three suggestive symptoms are noted early, swelling greater than usual, pain disproportionate to the injury and marked mental alertness The skin at first pale often appears bronzed on the first or second day In about one-fourth of the cases crepitus may be found on the first day, in one-third of the cases it appears on the second day, and in a smaller percentage on the third or fourth day In the more toxic edematous cases the crepitus is obscured by the edema and hence its recognition may be delayed to the second, third or fourth day.

The edges of the wound are often of a dirty creamy tint and there is little free pus, but at times bubbles of gas may be milked out with red-tinted serum having a disagreeable odor The toxic symptoms, with unimpaired intellect, appear early, less marked in the classic gaseous gangrene than in infections due to edema forming anaerobes

Treatment —The important phases of treatment are (1) Prophylaxis, (2) the use of antitoxins, (3) the removal of diseased muscles, (4) the question of amputation. If the condition is met promptly in the early stages, amputation will be seldom indicated All lacerated dirty wounds should be treated promptly by a thorough removal of all injured tissue, especially muscle After such débridement there should be left only healthy tissue with a good blood supply and in case of doubt adequate drainage should be established so that there will remain no dead spaces for the accumulation of extravasated blood The later the wound is treated the more radical should be the surgery. Here the wound should

be left more or less open and irrigations with Dakin's or other solutions instituted.

If infected with barnyard dirt in which animal excreta, especially liable to anaerobic contamination, is found, prophylactic antitoxin may be given In any case at the first appearance of gas it should be injected Owing to the probability of an infection with multiple organisms a polyvalent serum including antitetanic serum should be administered More investigation must be given to the sera to be included This will come with more careful study of the bacterial content of these wounds It should certainly include the antitoxins of Bacillus perfringens, vibrion septique, and Bacillus œdematiens It is possible that to this should be added the Bacillus histolyticus and fallax Where these cannot be obtained promptly it is possible that normal horse serum may have a detoxicating effect, generally, however, commercial brands of perfringens antitoxin and the vibrion septique at least can be secured which should be effective against these predominant organisms The various antitoxins as now prepared are not well standardized and the producers should be consulted as to the amount of dosage Milch uses a polyvalent serum containing 4000 units of tetanus antitoxin, 15,000 units of perfringens antitoxin, 35,000 M L D (minimum lethal dose) of vibrion septique, and 20,000 M L D of histolyticus antitoxin per 100 cc of saline solution Larson and Pulford use a polyvalent serum combining tetanus, perfringens, vibrion septique, and œdematiens antitoxins with a larger proportion of the latter two than Milch The time of the injection, severity of the infection, and tolerance of the patient must govern the dosage The injection is generally made intravenously diluted with normal salt solution A double dose is given immediately after the operation, a second smaller dose after four hours, then every twenty-four hours if necessary.

While some surgeons have depended upon serum alone it is wiser to institute surgical procedures promptly, particularly if there is any question of primary adequate débridement. The skin incisions should be extensive giving adequate exposure for a complete dissection. The muscle bodies should be examined and if one or more are found to be involved they should be excised *in toto* Clinically this will be recognized by their brick red color and non-contractibility. Intermuscular gas infected tissue should be opened widely to provide for postoperative irrigation No infected muscle tissue should be left This dissection and amputation, if performed, should be done with the cautery knife

When the infected area is widely opened the surgeon must decide whether to remove the diseased tissue only or to amputate the arm Where it is evident that the diseased muscles can all be removed the surgeon will generally be content with this unless he judges the infection to be predominantly of the edematous type which is of course much more fatal It is also true that it is difficult to remove all of the infected group of muscles in the forearm It is much easier in the upper arm The extent of the crepitation is a poor indication for amputation since this does not necessarily indicate a state of infection requiring such drastic treatment

In general one may say that in the more virulent type shown by edema, severe local and systemic reaction and in the simpler cases that show a tendency to spread in the next twelve hours after muscle ablation, amputation should be performed One is also more prone to immediate amputation where the injury is so severe or the ablation of muscle and other tissue so extensive as to leave a severely crippled arm even if recovery should take place under conservative treatment Wallace states that when gas gangrene occurs in a segment of a limb distal to the segment wounded it nearly always means

that the main artery is blocked and amputation of the gangrenous segment is the only course

Amputation when performed should be done well proximal to the infection and the stump left open for secondary suture after we are certain that the process is under control

The operative wounds in any case should be left widely open and irrigated every two hours by the Dakin technic with Dakin's or other solutions

The usual active supportive measures, large amounts of fluid, dextrose intravenously, and blood transfusions should be instituted if necessary There is marked tendency to acidosis so that the surgeon should watch constantly for this and institute alkalization promptly For this reason operations should be carried out under nitrous oxide or nitrous oxide and oxygen if possible.

PART III.

Lymphangitis, Major Fascial-space and Tendon-sheath Infections.

CHAPTER XV

DIFFERENTIAL DIAGNOSIS.

IT is the purpose of this chapter to give in brief the diagnostic factors of the three severe types of infection, viz , lymphangitis, tenosynovitis, and major fascial-space infection It is not intended in any sense as a complete discussion of any, but is introduced with the idea that by reading it the beginner may be able in any given case to make his diagnosis in general, and thus be directed for corroboration to the more extensive discussions found in the chapters upon anatomy, experimental injections and those devoted to the clinical considerations of these types In various parts indication is given where these can be found It is desirable to emphasize this, since the greatest difficulty to be met in these cases is the diagnosis Unfortunately, a snap diagnosis is too often made and incisions hastily carried out which jeopardize the life of the patient and the use of a hand, when a little more care in the diagnosis would have led to an immediate cure It should be emphasized, further, that if careful study is made it is possible in nearly every case to diagnosticate not alone the nature of the infection, but also the location of the pus if it be present.

There are certain facts which should be remembered.

1 The location of the greatest swelling does not indicate the position of the pus The excessive swelling comes in those areas where there is the largest amount of loose cellular tissue, *i. e* , upon the dorsum, while almost always the pus is on the flexor surface

2 *The site of the greatest tenderness is of marked importance* in the location of the pus.

3 The three types of infection, viz , lymphangitis, tenosynovitis, and fascial-space infection, in the majority of cases, are distinct processes, one type alone being present in a given case. At times the types may be combined

4 The treatment of the three types is essentially different, and the gravest of errors will be made if they are not differentiated, since their treatment is diametrically opposed

Let us now take up these three types in order.

LYMPHANGITIS

Lymphangitis may be either superficial or deep. Deep lymphangitis may end in tenosynovitis or abscess formation in the deep tissues Most often, however, this does not take place There is rapid increase of swelling of the whole hand and forearm, with the greatest redness, swelling, and tenderness upon the dorsum Some red lines of lymphatic infection may be seen running up the arm, to the axilla or elbow There is an absence of pain on extension of fingers and thumb The fingers can be moved voluntarily without pain, and there is an absence of tenderness over the tendon sheaths and the middle palmar and thenar spaces There is the absence of bulging of the palm, although exceptionally the concavity may be lost The patient often presents great prostration

The superficial type lacks the great swelling of the

entire hand and forearm. We receive a history of a slight abrasion or injury on the hand; within a short time the patient complains of all the symptoms of systemic absorption—headache, thirst, sleeplessness, restlessness, and fever. On examination we see locally an area of suffused redness, with a swelling of the finger which is involved. The color seldom becomes of that violaceous tint seen in abscess formation or the pallor which succeeds it In the most acute types there may be little or no edema, but most often one finds a considerable edema most marked upon the back of the hand. The swelling varies with the site of the invasion A general rule may be enunciated *The lymphatics pursue the shortest course to the back of the hand.* For example, if the infection enters at the distal part of the palm, the course will lie between the bases of the fingers. The lymphatics upon the dorsum will show up as bright red streaks running up the arm Ordinarily one or two only will be seen upon the back of the forearm, although there are fifteen to twenty here The lymphatics from the little finger and ring finger pass to the glands in the epitrochlear region, and except in the fulminating type these will be found enlarged From here the infection is carried to the axillary region and thence to the circulation The lymphatics from the thumb and index finger will be found coursing upon the back and outer side of the forearm and wending their way to the axillary glands without the intervention of the epitrochlear glands (see p. 105).

TENOSYNOVITIS

This type of infection is much more difficult to diagnosticate, and the surgeon is often in doubt as to whether he is dealing with a lymphangitis or tenosynovitis

The disastrous consequences of delayed diagnosis are so well known that the surgeon should study his cases

most carefully, since in nearly every instance an early diagnosis can be made and the function of the hand saved

The four cardinal symptoms and signs are

1 *Exquisite tenderness over the course of the sheath, limited to the sheath*

2 Flexion of the finger

3 Exquisite pain on extending the finger, most marked at the proximal end

4 Symmetrical swelling of the entire finger

These symptoms are seen to be only a difference in degree from those found in any infection of the hand, but when they are sought for in an intelligent manner there is not much difficulty in differentiating the conditions For instance, the symmetrical swelling of a tenosynovitis is distinctly different from the bulbous swelling of the distal phalanx seen in a felon

The size of the primary wound is of no importance The tendon sheath may become infected secondarily to a simple pin prick or an extensive wound. One finds only the cardinal symptoms I have mentioned, and in addition he may notice that the abutting sides of the adjacent fingers are swollen, as well as the back of the hand The whole of the involved finger is uniformly swollen The whole hand is slightly tender and the fingers are slightly flexed The involuntary expression of *pain which is noticed when the tendon sheath is touched* by the examining finger leaves no doubt in the mind of the examiner as to the location of the infection The greatest amount of tenderness is generally complained of at the proximal end of the finger sheath in the palm at the metacarpo-phalangeal articulation A difference is readily seen between the rigidity in the infected finger and the simple flexion in the adjacent digits So great is this difference that one is able to diagnosticate an extension into the ulnar bursa from the little finger sheath, since in the other fingers the character of the flexion changes

to the more rigid noted in tendon-sheath infection The spontaneous pain, which was at first severe, grows less as the edema develops, and this change may delude the surgeon into believing that the process is subsiding. The arm seems "to fall asleep," as the patient expresses it. Paresthesia with creeping and itching sensations may be present, and, especially after rupture of the sheath, the tenderness may subside to a considerable degree, leading the surgeon to an early erroneous conclusion

An infection of the sheath of the tendon in the little finger may be localized to the finger Extensions to other areas are possible, however The following are the most common (1) The ulnar bursa, (2) the radial bursa, (3) the forearm, (4) fascial spaces in the hand: (*a*) middle palmar space, (*b*) lumbrical spaces, (5) osseous involvement, middle phalanx, (6) joints, proximal interphalangeal, wrist, (7) rupture to the surface

Extension to the ulnar bursa is often difficult to diagnosticate It is marked by the development of edema in the hand, especially upon the dorsum A general fulness in the palm is seen, but the palmar concavity is still to be found On the flexor surface the greatest swelling is found just proximal to the transverse carpal ligament. This is not necessarily due to the rupture of the sheath here, but to the looseness of the tissues, which permits of distention The swelling is accentuated by the non-distensible transverse carpal ligament distal to it The swelling in the palm occurs at the same time, but is not so conspicuous, owing to the palmar fascia This also diffuses the swelling so that it is not accurately limited by the outline of the ulnar bursa Moreover, the surrounding edema tends to confuse the picture

The most conspicuous and valuable sign is the extension of the exquisite tenderness to the area involved, found especially at the point just proximal to the point where the distal flexion crease of the palm meets the hypothenar

eminence. It should be remembered that this is absent after a few days The wrist becomes fixed, the thumb shows tenderness to pressure, and particularly on passive movements is the sensitiveness noted. It is seen readily of how much importance the latter symptom is in diagnosticating an extension to the ulnar bursa from the little finger We note that while at first the symptoms are limited to the little finger and slight changes in the ring finger, because of its juxtaposition, all at once the thumb begins to show the characteristic signs while the index and middle fingers remain unchanged except for the increase of pain on passive extension explained above This sensitiveness of the thumb may be due either to the juxtaposition of the sacs, or to a real extension into its sheath At first there may be a diffuse redness of the palm and dorsum, but it rapidly gives place to a whitish or even cyanotic hue Above the wrist, however, the tissues generally take on a marked red color, which later becomes violaceous

Extension from the ulnar bursa to the radial bursa is diagnosticated by the increased swelling and tenderness in the thenar eminence and along the sheath with fixation of the thumb The tumefaction of the thenar area is not that of abscess in the thenar space (see p 381).

The temperature and pulse may not be of any diagnostic importance Ordinarily, after the infection has lasted a few days and the walling-off process has begun, the temperature is that of the local accumulations of pus and varies with the freedom of drainage. The first few days, however, the systemic absorption bears no relation to the abscess formation and cannot be relied upon for diagnostic purposes.

From the bursa various extensions frequently take place into the fascial spaces of the hand and forearm The symptoms and signs of this extension will be taken up under the head of "Fascial-space Infection".

Involvement of the index, middle, and ring fingers

presents the same signs as the little finger. The only difference is that here the paths of extension are different. Besides the extension to the surface at the proximal end, involvement of the middle phalanx and the proximal interphalangeal joint, the finger may show extension to the lumbrical spaces on either side, and from here involve the adjacent tendon sheath (see p 372)

Diagnosis of extension from a tenosynovitis of the thumb into the radial bursa and then into the ulnar bursa is more difficult For the diagnosis of extension to the radial bursa we must depend upon the extension of the tenderness to the area over its distribution and the tenderness above the transverse carpal ligament. When the extension has proceeded over into the ulnar bursa, the diagnosis is easier, since all of the fingers become painful to passive extension, most marked the little finger, with tenderness over the area of the ulnar bursa particularly just proximal to the point where the distal flexion crease of the palm meets the hypothenar eminence (see p 377)

The pus from the radial bursa frequently ruptures into the tissues of the forearm, and then the pus lies under the flexor profundus tendons just as in rupture of the ulnar bursa (see pp 371 and 379)

MAJOR FASCIAL-SPACE INFECTIONS

Pus may be found in various spaces in the hand and forearm, as I have already pointed out in the discussion of the anatomy This may occur as a primary infection or secondary to lymphatic or tendon-sheath infection, especially the latter. I have demonstrated by injection and serial sections the spaces in which such accumulations can take place These well-defined spaces are six in number.

1 Middle palmar space
2 Thenar space

3. Hypothenar space.
4. Dorsal subcutaneous space
5. Dorsal subaponeurotic space
6 Major forearm space.

The thenar and middle palmar spaces are by far the most important and most frequently involved in the hand.

The major forearm space is a definitely outlined and very important space Briefly, it can be stated that pus which has extended from the hand to the forearm always lies under the flexor profundus, upon the pronator quadratus and interosseous septum. It passes upward, following the ulnar artery, going as high as the elbow (see p 388)

Now, how shall we diagnosticate an involvement of these various spaces? First, upon the probability of extension from other foci. The middle palmar space would receive infection by extension from the middle finger, ring finger, little finger, also from the ulnar bursa and localized infections in the lumbrical canals between the heads of the metacarpals Again, it may be involved by direct implantation or through osteomyelitis of the middle and ring metacarpals It is possible for a thenar space abscess to rupture into the middle palmar space (pp 338 and 379)

The thenar space might receive the infection from the index finger or thumb, or by direct implantation, or by osteomyelitis of the index or thumb metacarpals, and finally it would be possible for the space to become involved secondarily to the middle palmar space (see pp. 339 and 381)

The forearm may be involved by rupture from either the ulnar or radial bursa (see pp 92 and 371) The source of the involvement of the other spaces can be readily surmised (see pp 326 and 356).

When the middle palmar space is involved we notice

that whereas earlier there had been a fulness in the palm without loss of the concavity, now the concavity begins to be lost, and as the process becomes marked, a slight bulging of the palm is noticeable in spite of the palmar fascia The correlation of this with tenderness is of especial value Early, before the swelling becomes marked, the tenderness is exquisite and limited by the outlines of the middle palmar space, but as the swelling increases, the tenderness and especially the spontaneous pain grow less There is generally more or less extension along the lumbrical canals, so that the swelling of the area between the heads of the metacarpals adds to the general picture The areas may be red, but generally it is pallid. With this there is found the flexion of the fingers due to the juxtaposition of the tendons to this area They are held rigidly flexed, decreasing in rigidity from the little finger to the index finger The latter may have considerable voluntary motion If the pus has extended along the lumbrical canals to the base of the fingers, there may be swelling and induration in the loose tissue of the web, and an accumulation of pus may be found to have extended to the dorsum between the bases of the proximal phalanges The relation of the swelling in the palm to that in the thenar area is of great importance In involvement of the middle palmar space there is an associated swelling of the thenar space of almost the same degree as that of the middle palmar space, but this is due to edema When the thenar space becomes involved the swelling is out of all proportion to that of the palm if it be involved There is the induration of infection rather than the softness of edema The thenar space will look as if a balloon had been inserted into the area and blown up to its full capacity I know of no clinical picture in surgery that is more characteristic than this of thenar-space infection, and having once seen it one cannot forget it. Besides the ballooning of the thenar area, the metacarpal of the thumb is

pushed away from the hand; the flexion of its distal phalanx becomes more marked, though lacking the rigidity found in involvement of the tendon sheath of the flexor pollicis longus. This infection of the thenar space may be primary and isolated or secondary to a middle palmar infection (see pp. 326 and 332).

The edema upon the back of the hand is always present and the swelling much greater, of course, than in the palm, even though the latter be the site of the pus. It is extremely uncommon to find any pus upon the dorsum unless there has been a lymphatic infection or the pus has extended, as already described, between the metacarpals of the index finger and thumb from the thenar space, or between the bases of the proximal phalanges We should bear in mind that edema gives rise to a soft pitting, while if pus be present induration can always be felt. If this fact is borne in mind many embarrassing mistakes will be avoided I think that in three-fourths of the hands I see in which treatment has been instituted a number of unnecessary and improper incisions are found upon the dorsum

The forearm may be involved from a tenosynovitis of the ulnar or radial bursa In these cases the pus occupies the major forearm space. As has been pointed out, the pus in these cases passes between the pronator quadratus and the flexor profundus to the area between the latter and the interosseous membrane, and at about the middle of the area it passes more superficially and to the ulnar side along the ulnar artery and nerve This extension is characterized by a brawny induration that should not be confused with the softness of an edema No fluctuation should be expected, since the accumulation lies too deeply If the primary source is the ulnar or radial bursa, this extension is marked by the loss of the relative swelling immediately above the transverse carpal ligament, due to the distended upper end of the sheath This swelling is

not any less, but that of the arm is greater. The tenderness may become less, so it cannot be depended upon as a symptom The redness is generally greater, and spontaneous pain, while at first marked, rapidly subsides. At this time some pus may accumulate subcutaneously above the wrist and lead to the supposition that there is no pus under the tendons Thus valuable time is lost (see pp 332, 371 and 388)

Involvement of the hypothenar space can often be prognosticated from the site of the primary injury, while the relative lack of swelling in the palm and fingers, with absence of involvement of the tendons, combined with the ordinary symptoms of abscess lead us to an easy diagnosis Fortunately, the hypothenar area is so separated from the remainder of the hand that it is not involved secondarily to palmar infection

An infection localized upon the dorsum under the subaponeurotic fascia to the exclusion of the subcutaneous tissue may be difficult of differential diagnosis However, we are aided materially if we remember the character of the primary injury, the methods of extension to this space already mentioned, and the local evidences of infection upon the dorsum, with the pitting edema of the subcutaneous tissue, yet lacking the brawny induration and localized tenderness of a subcutaneous abscess (see pp. 90 and 340)

We may be in doubt as to whether we are dealing with a tenosynovitis of the dorsal bursæ or a rheumatism of the wrist In those cases presenting an apparently spontaneous development of an inflammation at the wrist, the diagnosis may be most difficult in spite of the ease with which a theoretical differential diagnosis is made Here again, however, the localized tenderness over the sheaths and pain on movement of the fingers are of the greatest importance In a rheumatism there is as much pain on the volar as on the dorsal surface and other joints

may be involved. The presence of a gonorrhea does not aid us materially since either complication may follow In one case it was difficult to determine whether the patient was suffering from a gonorrheal rheumatism of the proximal interphalangeal joint of a finger or a gonorrheal tenosynovitis with secondary involvement of the joint. The latter assumption was later found to be the condition present.

DIAGNOSIS OF EXTENSIONS FROM VARIOUS SITES

The diagnosis of the extensions from various sites is of the greatest importance from a therapeutic standpoint I have worked out these probabilities by both experimental and clinical observations The present chapter is too brief to allow a full discussion I shall, however, append a tabulation, with references attached, denoting where a complete discussion of each subject can be found

If the infection originates in the thumb, for possible extensions see pp 341 and 377

If the infection originates in the index finger, for possible extensions see pp 342 and 372

If the infection originates in the middle finger, for possible extensions see pp 350 and 372

If the infection originates in the ring finger, for possible extensions see pp 352 and 372

If the infection originates in the little finger, for possible extensions see pp 353 and 367

If the palmar space is involved, for possible extensions see pp 332 and 355

If the thenar space is involved, for possible extensions see p 337

If the forearm is involved, for possible extensions see p 388

If the ulnar bursa is involved, for possible extensions see pp 63 and 367

If the radial bursa is involved, for possible extensions see pp. 68 and 377.

CHAPTER XVI

ETIOLOGY, PATHOGENESIS, AND PATHOLOGY OF LYMPHANGITIS.

PREDISPOSING AND ACTIVE FACTORS IN THE PRODUCTION OF LYMPHANGITIS

WHILE a lymphangitis may develop at any time of the year, it is most frequently observed in the fall and winter, an observation that is concurred in by all authors This may find its cause in the unnatural conditions under which workingmen live during the colder months, at which time they are closely housed, with the result that they breathe impure air, and because of this and the lack of outdoor exercise their power of resistance is reduced It is possible that the colder air which contracts the superficial vessels may have some bearing on the development of the infection by lessening the natural protection against superficial injuries.

The source is most often some slight puncture, carrying bacteria beneath the surface, or the small crack so often found in workingmen's hands, especially in winter, about the calloused areas, the so-called *durillon force* of the French authors These are particularly noted at the distal part of the palm, where dirt incident to the occupation is rubbed into the fissures The slight punctures often come from needles or pins, and are thus frequently found on the distal phalanx, generally being so slight as to have been forgotten when the patient applies for treatment Again, we note its frequency after trauma of the nail The patient gives a history of running a splinter under the nail, or of some injury which has caused a separation of the nail from its bed, with a small subonychial hemorrhage, which has become infected.

Why it is that similar injuries may be followed in one case by severe lymphangitis and in another by no results is still an unanswered question. We are accustomed to say that the resistance of the patients varies, and this is undoubtedly true. On the other hand every surgeon has seen many cases of severe lymphangitis in patients of

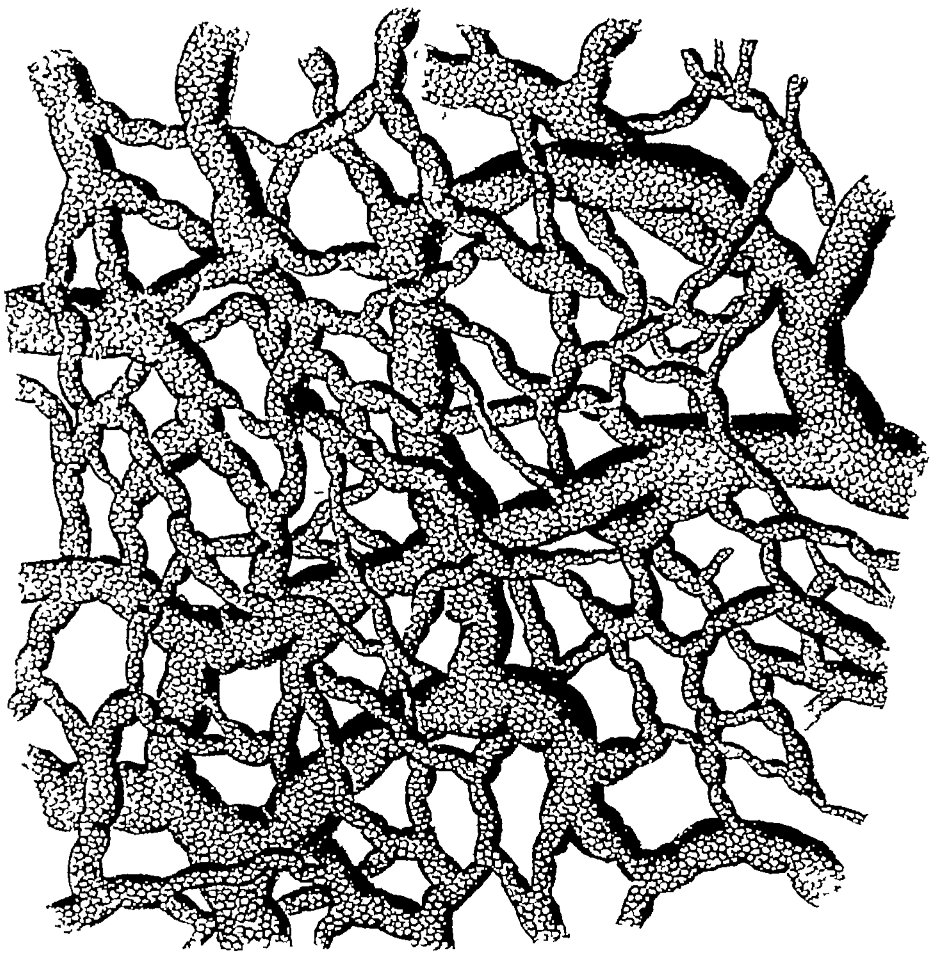


FIG 108 —Showing lymphatics in the palm of the hand (After Sappey)

apparently normal resistance We cannot attribute the cause entirely to lessened resistance. It is possible that some bacteria contain inherent cytolytic attributes which lessen the possibility of the walling-off process and favor extension Many investigators have studied the question and added individual facts to our knowledge, which is inadequate, however, for a complete understanding of

the subject Cannon showed the ligation of the small intestine favored bacterial growth in the blood stream, thus showing the importance of proper intestinal action.

THE INFLUENCE OF THE TYPE OF GERM

It is probable that almost any of the various pathogenic bacteria may give rise to lymphatic infection In a great majority of cases, however, the streptococcus will be found to be the etiological factor. No group of bacteria can claim more varied and more numerous types of proved and possible pathogenic activity than the streptococci. The classification is still the subject of a great deal of controversy Attempts have been made to classify them according to the size or appearance of the individual cocci, their arrangement in pairs rather than in chains, the length of the chains themselves, according to their growth in culture media, according to their sugar fermentation, according to their origin and according to their virulence The variability of many of the different characters makes classification and nomenclature difficult. The action of the streptococcus, nevertheless, on red blood corpuscles is most significant and important It is possible to differentiate strains which will hemolyze blood, others which produce green colonies and still others which fail to produce any change on blood This has given rise to the widely used classification of Streptococcus hemolyticus, Streptococcus viridans and Streptococcus non-hemolyticus The majority of authors who have used the blood method have proceeded further to classify by employment of carbohydrate tests Of these, Holman's is probably the most satisfactory and the most generally used classification of the streptococcus group His method consists in a primary differentiation of hemolytic and non-hemolytic strains by streaking out on blood agar followed by a further segregation of each by the action on three sugars, lactose, mannite and salicin By this

method sixteen types, eight hemolytic and eight non-hemolytic, are differentiated. Under the non-hemolytic are included viridans cultures as well as those which have no effect upon blood mediums Of the hemolytic forms Streptococcus pyogenes and Streptococcus anginosus are the most important pathogenically. Brown, by the reaction on blood agar plates divides the streptococci into the alpha, beta, alpha prime and gamma types. The many attempts to classify streptococci by serological methods, mainly by agglutination with specific antisera correlated with agglutinin absorption tests do not offer any practical system The individual groups of streptococci are not specific in their disease production. The members of the hemolytic group are commonly more virulent and pathogenic, producing more rapid progressive disease while the Streptococcus viridans or mitis is found particularly in association with the milder, more chronic group of infections with certain definite locations

The next microorganisms of importance are those of the Staphylococcus groups The most noteworthy members of this group, in this connection, are the Staphylococcus pyogenes aureus, the Staphylococcus pyogenes albus and the Staphylococcus pyogenes citreus The Staphylococcus pyogenes aureus is characterized by a golden yellow pigment Separate strains show wide variations in relative virulence, the most highly virulent usually being those recently isolated from human suppurative lesions Hemolysins are produced by Staphylococcus aureus and to a less degree by Staphylococcus albus The quantity produced varies enormously with different strains and seems to be roughly proportionate to the virulence of the particular microorganisms Absolutely avirulent races do not, apparently, produce hemolysins Staphylococcus pyogenes albus differs from Staphylococcus pyogenes aureus simply in the absence

of the golden yellow pigment. Morphologically, culturally and pathogenically it is in every way identical but its toxin and enzyme-producing powers in general are less developed. Staphylococcus pyogenes citreus forms a bright yellow or lemon-colored pigment It may be pyogenic but it is less often found in connection with pathological lesions than either of the above Many of the other types of bacteria may be found in the systemic infections, even the Bacillus pyocyaneus has been found in a number of cases, as instanced by Roberts, Finkelstein, and Brill and Libman

Among the most marked characteristics of severe infections we have the cytolytic and hemolytic functions The semi-jaundiced appearance of the severe cases due to the hemolysis is a well-known picture, and while most often seen with streptococcus infections, it may also appear in the staphylococcus forms to a marked degree, especially in the aureus infections and to a lesser degree in albus. This staphylohemolysin must, however, be present in considerable amounts before its effects become apparent in man, since his serum contains normally small amounts of anti-staphylolysin, as was shown by Neisser, and, moreover, if the inoculation or infection begins slowly, the system will develop larger amounts

The effect of symbiosis is not fully known, although it has been hinted at by various investigators The effect of combined streptococcus and staphylococcus involvement is of special interest, since we so often see this combination Fisher and Levy suggest that the streptococcus through its rapid spread prepares the soil for the staphylococcus. When this occurs the prognosis is more grave, since the combination seems to increase the virulence of the streptococci I personally have observed that such cases have a convalescence prolonged much beyond the ordinary course seen in patients infected

with either separately, and this emphasizes the necessity of careful asepsis in the care of any infection. The synergistic action of bacteria is considered in more detail in the chapter on "Gangrenous Infections."

THE INFLUENCE OF THE ANATOMY ON THE COURSE

A general rule which the anatomy emphasizes is that from any given point the superficial lymphatics pursue the shortest course to the dorsum. An exception is made of the center of the palm, from which, as has been shown, an infection would tend to go down to the superficial palmar arch. These are rare, however The general rule of the dorsal extension explains the frequency of great edema on the back of the hand in all cases As specific examples of the importance of this observation, those infections arising at the distal part of the palm should be noted Here the lymphatics first go distally, then pass around the web and onto the dorsum, at which site the swelling and redness are seen, giving rise to the assumption on the part of the thoughtless that the infection is primarily there. This is then followed by unnecessary and harmful incisions A little care would have shown that the starting-point was a slight fissure in the callus on the flexor surface, and that the dorsal redness was lymphatic in nature, accompanied by an inflammatory edema which would be harmed rather than helped by an incision. The same is true of infections upon the ulnar and radial sides of the palm Where there is localized redness on the dorsum of the hand we less often see the dorsal lines of redness running up the arm These are generally the accompaniment of an absence of local reaction

Along the course of the lymph vessels will be found areas of redness and edema about twice the width of the redness accompanying the vessels, appearing as if the infection were localizing there or as if small abscesses were forming.

These may be incised under that assumption. It is doubtless true that in the semiacute cases, or those going on to abscess formation, the localizing processes may start from these foci, but great care should be exercised before making this deduction, since these are but the evidences of the lacunæ mentioned in the anatomical

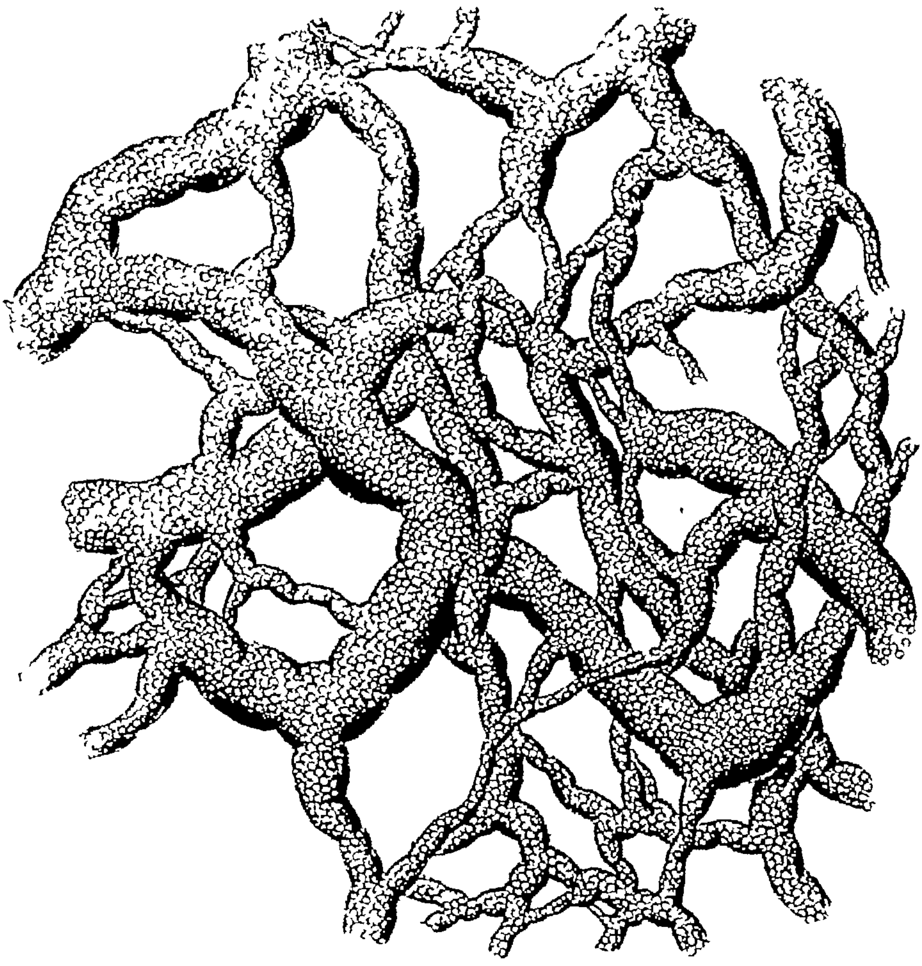


Fig 109 —Showing lymphatics in the skin and around the nail in a child, aged four years (After Sappey)

discussion, and generally subside at the same time the inflammation disappears from the vessel proper.

Attention should also be drawn to the normal course of the vessels, and it should be emphasized that lymphatic extensions from the little and ring fingers take place through the epitrochlear glands, then to the axillary, while infections beginning in the thumb and forefinger

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involved The distal phalanx itself, the site of the primary injury, would show little or no serious consequences This will be discussed more fully under symptomatology

If the deep lymphatics are involved, the course naturally follows the course of the veins, as has been previously

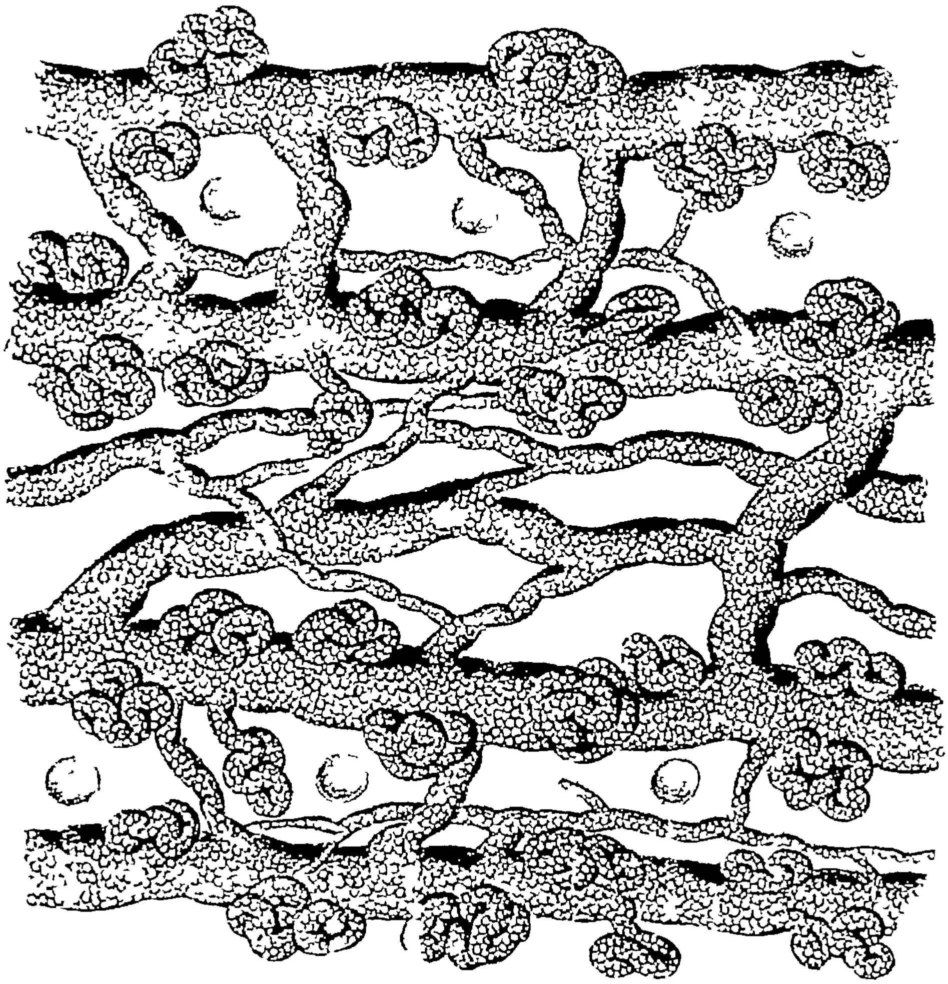


FIG 110 —Lymphatics about one of the palmar flexion creases (After Sappey)

pointed out Exceptionally abscesses may develop along the line of these vessels If it be the interosseous, the abscesses will naturally lie under the flexor profundus, thus occupying the site I have already pointed out as that in which the deep abscesses spreading from the tendon sheaths are always found

go to the axillary glands without the interposition of the epitrochlear; hence systemic infection is more easily engendered, and, moreover, if the observer were searching for glandular enlargement he would not expect to find it at the elbow in these cases Infections beginning in the middle finger are of special interest in that either the axilla or the epitrochlear glands may be first involved, and in some cases neither of these areas may receive the lymphatic vessels, since they may pass up over the clavicle and into the subclavian glands and thus directly into the circulation The clinical importance of this lies in the fact that these infections may reach the circulation very early and because of the rapidity of involvement lead to severe and even fatal systemic infection I have seen several cases that lends support to this assumption Therefore one would look with great anxiety upon severe infections arising from the middle and index fingers

In some of the patients the lymphatic infection rapidly spreads from the lymphatic vessel and extends over the entire dorsum of the hand and forearm with the appearance of an erysipelas without the raised border The swelling is considerable, the skin takes on a board-like hardness, and vesicles may appear on the surface This may subside without further trouble, but very often subcutaneous tissue soon becomes involved with necrosis of the subcutaneous tissue and diffuse abscess formation (See "Gangrenous Infections.")

There is an intimate relation between the lympatics of the digits and the tendon sheaths Of this I have no anatomical proof, but such clinical evidence that there can be no doubt of the association It has been my experience frequently to meet with infections from pin pricks, especially of the distal phalanx, which lead to a typical lymphangitis with a red line running up the arm, and after a couple of days these would show the typical evidences of tendon-sheath infection of the finger

examination shows the destruction of the endothelium produced by a virulent toxin. Adami has emphasized the important part the endothelial cells play in inflammations, in that they may act as phagocytes and may undergo changes to giant cells or other forms more fitted to combat the process. A cross-section will show these changes, and in addition may show the vessels filled by a thrombus made up of cells and bacteria, and in those cases where the thrombus lies close to the wall the bacteria may be seen in that also. If the vessel is injured or cut, the bacteria spread beyond the wall, but in the ordinary simple case they will be found confined to the wall and the lumen The bacteria do not seem to be in the leukocytes to any great extent, but they are so mixed together in the thrombus as to leave some doubt in my mind on this point At some points I have found the thrombus entirely free from bacteria, in which case it may be reasoned that the toxin has produced the thrombus in advance of bacterial extension In some instances, in spite of the changes in the lumen, the vessel wall showed little change The endothelium was not changed. There were no endothelial giant cells. The connective tissue about showed the evidences of inflammation with moderate round-celled infiltration, although this did not extend far into the adjacent areas The capillaries were engorged with blood for some distance, and the connective-tissue fibers were separated by the serous exudate If the inflammation is a chronic one, all of the changes incident to such infection are seen If the vessel is cut, there is a rapid extension to the surrounding tissue, which macroscopically takes on the appearance of an erysipelas and pathologically shows the inflammatory changes associated with it About the lacunæ the changes I have just described are most marked, a much wider area about them being involved

The lymph glands show nothing different from the

If the lymphatic vessels along the radial and ulnar vessels are the source, the abscesses will naturally lie along these vessels. It has not been my experience to meet with any such cases, and I am inclined to believe that their occurrence is uncommon. I have seen abscesses along the brachial vessels, however In one case it developed as an extension from a deep infection of the forearm, and in another as the sequel of a typical superficial lymphangitis of the forearm. It seemed to me reasonable in this latter case to ascribe its development to suppuration in a lymphatic gland lying in juxtaposition to the vessel, since we know that, while these glands ordinarily lie at the elbow and axilla, they may occur at any part of the lymphatic stream. From the very nature of the cases we would expect deep lymphatic abscesses to be uncommon

THE PATHOLOGY OF LYMPHANGITIS

The pathology of these cases concerns itself particularly with the changes in the lymph vessels and glands, and need not be discussed in completeness, since the general facts are well known A picture of the condition found in a typical case will be as follows:

The local changes at the site of injury may be so insignificant as to escape notice The local reaction, even in a case that threatens lethal issue, may be nothing more than a slight redness indicative of a hyperemia There is no hardness suggestive of the outpouring of the protective leukocytes with the coagulation of the lymph and blood elements about a site of injury and infection, as is seen in the localized staphylococcus infection, although great pain may be present. This is particularly seen in the distal phalanx, where the differential diagnosis between this condition and a beginning felon must be made.

The lymphatic vessels are evidenced by their redness, the hyperemia surrounding them, and a microscopic

The little finger and ring finger drain into the epitrochlear glands and then to the axillary A small percentage of infections beginning in the middle finger pass directly up over the clavicle and into the subclavian glands without passing through either the epitrochlear or axillary glands The thumb and index finger drain into the axillary glands.

Deep lymphatic abscesses are uncommon

Abscesses following the deep lymphatics will lie along the vessels If one develops along the radial artery, it will appear on the radial side of the arm in the lower third If the abscess extends upward, it will enter the deeper portion of the arm and will become a submuscular abscess If along the ulnar vessel, the pus will readily come to the surface between the flexor carpi ulnaris and the flexor digitorum sublimis

The pathological change in the lymphatic vessels is that observed in any inflammation

In an exceptionally severe case, marked sloughing of the entire subcutaneous tissue may occur

ordinary picture seen in varying inflammations of their structure Systemically in severe cases marked changes in the blood and various organs are found which will be discussed when speaking of the fatal cases

In the severe cases locally we may find that the subcutaneous tissue and even the skin may become gangrenous Of course the former is most common Here an abscess will form, and when opened large sloughs of connective tissue may be removed from which the streptococcus may be secured in pure culture. (See "Gangrenous Infections")

RÉSUMÉ

The source of lymphangitis is frequently an injury so slight as not to be recognized or remembered by the patient It is probable that in the majority of cases the organism at fault is the streptococcus, but various pathological organisms may be found

Gonorrheal lymphangitis occurs as a result of systemic infection

While hemolysis is often a marked accompaniment of streptococcus lymphangitis, it is not necessarily present The effect of symbiosis is not definitely determined but it apparently adds to the morbidity

The lymphatics pursue the shortest course to the back of the hand, consequently infection at the distal portion of the palm will spread around the web into the dorsum. In case of local infection in the palm the swelling of the dorsum, due to edema, may be very great, even greater than on the palm Care should be exercised not to incise on the dorsum but in the palm if localized abscess is present

Small areas along the inflamed lymphatic, the size of a small pea, which appear red and swollen, indicate lacunæ in the course of the vessels and are not an evidence of localized infection and should not be incised

however, these severe symptoms are delayed two or three days, even though there may be a severe onset with a chill, temperature, and headache.

TYPES.

Four types may be seen

TYPE I. SIMPLE ACUTE LYMPHANGITIS.—If the process subsides, the physician may be surprised at the rapid disappearance of all evidences of the infection, both systemic and local. All objective evidences may entirely disappear in from twenty-four to forty-eight hours The red line of lymphatic inflammation may disappear over-

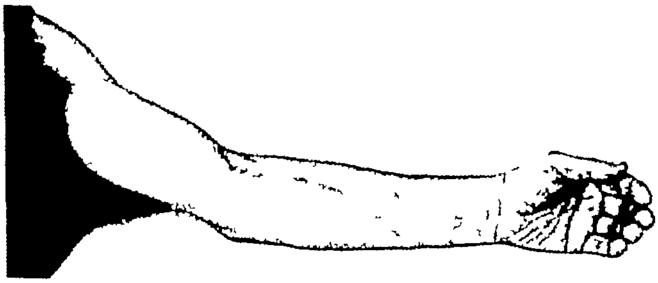


FIG 111 —Lymphangitis of the arm from an infected abrasion on back of hand Thirty-six hours in the hospital with continuous hot dressings relieved this condition without surgical interference (Mock)

night with slight tenderness over the gland area persisting for a few hours longer.

TYPE II. ACUTE LYMPHANGITIS WITH MINOR LOCAL COMPLICATIONS —In a second group the symptoms may subside more slowly and end in a delayed resolution or even abscess at the site of inoculation or in the gland area accompanied by mild systemic symptoms

TYPE III. ACUTE LYMPHANGITIS WITH SERIOUS LOCAL COMPLICATIONS —In a third group of cases complications arise ending in tenosynovitis or subcutaneous abscesses. These cases are accompanied by severe pain early in the course and symptoms more or less grave which arouse the anxiety of the physician, early, as to the possibility of

CHAPTER XVII.

SYMPTOMS AND SIGNS OF LYMPHANGITIS WITH DISCUSSION OF THE COMPLICATIONS AND PROGNOSIS.

SYMPTOMS AND SIGNS IN GENERAL

A PATIENT with a lymphangitis ordinarily gives a history of a slight abrasion or pin prick, which had been considered of no importance. Frequently no history of injury can be secured The patient has noticed a slight malaise or chilly sensations, possibly a severe chill may be noted There may be no local pain in the hand or arm and no swelling. Generally, however, there is slight swelling accompanied by a dull pain, and at times the edema on the dorsum may become marked and the pain very severe. The symptoms and signs bring the patient to the physician, who finds in addition to the local condition red lines running up the forearm and arm corresponding to the anatomical distribution of the lymphatic vessels draining the area of primary infection. There may or may not be tenderness or swelling in the region of the epitrochlear or axillary glands Generally, however, after the infection has lasted twenty-four hours some tenderness and swelling are found. The arm as a whole may show some slight swelling, although this is generally absent.

The degree of systemic involvement varies in the widest limits In some cases, even early in the course, the patient will present the evidences of severe toxemia with a chill and high or low temperature, headache, anorexia, and prostration. In a majority of cases,

induration suggestive of localized pus, the incision would do little good, and might open new avenues for absorption There could have been no question as to making incisions at other points Upon the third day our conservatism was rewarded by seeing the pain disappear from the distal phalanx as well as the red line of lymphatic involvement in the arm The patient now located and limited the tenderness to an area over the tendon sheath of the index finger There was no increase of the swelling of the distal phalanx, although the finger as a whole had taken on the full appearance characteristic of distention of the sheath with pus. The tendon sheath was opened and the pus evacuated, following which the patient ultimately recovered with a preservation of the finger It should be noted that no incision was made into the distal phalanx, although that was the site of the original pain and tenderness Moreover, upon the second day it was certainly impossible to make the diagnosis of tenosynovitis.

Case VIII —Mr Geo W applied to the dispensary of the Post-Graduate Hospital with a history of having had a small cut upon the ulnar side of the palm Suddenly, after three days, he suffered from a chill and felt feverish The hand began to swell, especially upon the dorsum Upon examination the remains of a small cut could be seen upon the palm, but there was no evidence of inflammation about it No localized tenderness or swelling The dorsum of the hand, especially upon the ulnar side, was greatly swollen and reddish The skin of the entire dorsum was red There was no subcutaneous induration, and the skin itself, while red, did not have the induration found in erysipelas A red line of lymphatic involvement ran up on the dorsum of the forearm, and could be traced to the epitrochlear region and then along the inner side of the arm to the axilla Tender glands could be palpated in both regions Temperature, 103° F , pulse, 100

The question arose whether or not an incision should be made over the tender swollen dorsum It was reasoned that this was not indicated, since there was no evidence of a localized abscess here or of a diffuse phlegmon, which

death from systemic infection, and later, as to the diagnosis of the seat of the secondary abscesses and the possible necessity for amputation.

TYPE IV ACUTE LYMPHANGITIS WITH SYSTEMIC INVOLVEMENT —In a fourth group the process may give rise at once to most alarming systemic symptoms and with or without local difficulty end fatally in a few days

The first and second groups are easily classified and understood, the third and fourth may require a more extensive consideration.

ACUTE LYMPHANGITIS WITH SERIOUS LOCAL COMPLICATIONS

The third type may be a constant source of anxiety, and the surgeon is often in doubt as to the ability of the patient's resistance to cope with the infection, and he is constantly questioning the correctness of his diagnosis as to the position of pockets of pus and the adequacy of his treatment It may clear up the picture somewhat to illustrate this by one or two examples.

CASE VII —A patient, Mr L W, was seen by me on the second day of his infection He had injured the forefinger of his left hand with a piece of fine, rusty wire which had penetrated the distal phalanx upon the volar surface He was complaining of severe pain in the entire finger, but most marked in the distal phalanx An examination showed that the entire finger partook of a pinkish hue, and was somewhat swollen throughout The distal phalanx, while the most painful and tender, lacked the induration characteristic of localized infection A red line ran up the back of the hand and forearm and could be traced to the axilla, where slightly tender glands could be palpated He was profoundly ill, with a temperature of 104° to 106° F

The proper procedure was considered to be that of applying a hot boric solution dressing, rest both local and general, eliminatives, and sedatives. The question immediately arises as to the advisability of incising the distal phalanx It seemed to me that lacking the

induration suggestive of localized pus, the incision would do little good, and might open new avenues for absorption There could have been no question as to making incisions at other points. Upon the third day our conservatism was rewarded by seeing the pain disappear from the distal phalanx as well as the red line of lymphatic involvement in the arm The patient now located and limited the tenderness to an area over the tendon sheath of the index finger There was no increase of the swelling of the distal phalanx, although the finger as a whole had taken on the full appearance characteristic of distention of the sheath with pus The tendon sheath was opened and the pus evacuated, following which the patient ultimately recovered with a preservation of the finger It should be noted that no incision was made into the distal phalanx, although that was the site of the original pain and tenderness Moreover, upon the second day it was certainly impossible to make the diagnosis of tenosynovitis.

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The question arose whether or not an incision should be made over the tender swollen dorsum It was reasoned that this was not indicated, since there was no evidence of a localized abscess here or of a diffuse phlegmon, which

at times accompanies erysipelatous infection in this region Conservative treatment was therefore instituted with a rapid cessation of all symptoms in the hand and lymphatic vessels. However, the tenderness gradually increased in the epitrochlear region, and a redness which had not been present before now appeared At the end of seven days a suppuration which had had its origin in the gland here was diagnosticated Drainage was instituted, with complete recovery in a short time.

PHLEGMONOUS LYMPHANGITIS —One of the most serious types is that in which the infection seems to involve the skin of the back of the hand and forearm like an erysipelas The toxemia is great, the forearm greatly swollen, and the board-like skin shows small blebs or blisters upon its surface The bacteria soon invade the subcutaneous tissue and lead to a destruction of areas of the subcutaneous tissue *en masse*, thus leaving the infected skin without proper blood supply Consequently, large pockets filled with pus and seminecrotic tissue underlie the skin of the dorsum, which itself soon becomes gangrenous in spots. Meanwhile, the patient is suffering from a severe toxemia or sepsis. The superficial veins may become thrombosed and threaten life by acting as the source of infection, even though the lymphatic absorption may have ceased The greatest care should be exercised in differentiating this type from the swollen, reddened, edematous form seen in ordinary lymphangitis, in which there is no induration of either the skin or subcutaneous tissue This subject is considered in detail in the chapter on "Gangrenous Infections"

Examples of these types could be multiplied many times in my experience The early signs and symptoms very commonly point to an entirely different area as the probable site of abscesses than the one in which it ultimately develops, and I wish to emphasize, therefore, that the diagnosis of the accumulation of pus should be made

only upon positive signs After once localizing, the abscesses follow the definite lines laid down in the chapters upon Tenosynovitis and Fascial-space Infection.

THE FREQUENCY OF LOCALIZATION IN LYMPHATIC INFECTION.—The frequency with which localization takes place in lymphangitis is hard to state accurately. In my experience 10 to 15 per cent of the cases would probably be nearly correct, and if anything, it would be less rather than more than that. The sites of such involvement are ordinarily the tendon sheaths of the respective finger, the dorsum of the hand, the dorsum of the forearm, the axilla, and the epitrochlear region Secondary to tendon-sheath infections and deep infections of the hand, it is common to find a subcutaneous accumulation of pus of lymphatic origin on the flexor surface of the wrist From these observations it is very evident that a great majority of the cases of lymphangitis subside without secondary abscesses unless they are engendered by ill-advised incisions

ACUTE LYMPHANGITIS WITH SYSTEMIC INVOLVEMENT

In our classification we have included in this group those severe infections which through systemic absorption or infection threaten or destroy the life of the patient They may arise from any source or in any individual They are more likely to occur in individuals over thirty-five years of age, and, if fatal within a short time, are more inclined to follow infections of the thumb, index or middle fingers The little finger is the origin of some fatal cases, but here the lethal issue is often due to infection through involvement of the tendon sheaths with improper drainage In other words, death is the outcome of two types of infections. (1) An acute type without localization in the hand, and (2) a severe type with localization, subsequent toxemia from inadequate drain-

age, and the inability of the patient's system to wall off the infection, ending in death from exhaustion and sepsis.

Deep lymphangitis as a clinical entity is rare and its diagnosis must often remain in doubt, since it is generally associated with a superficial inflammation, at times showing red lymphatic lines, but generally appearing as of the erysipelatous type. The whole arm and forearm are swollen It will be noted that this is different from the appearance in superficial lymphangitis, in which the back of the forearm is swollen out of proportion to the front The patient is generally profoundly ill with all the evidences of toxemia In no case that I have had has there been any localization of pus about the deeper portion of the arm In one patient an abscess localized itself along the radial artery about 2 inches above the wrist This was subsequently drained, with recovery of the patient I have not seen any cases of deep forearm abscesses which could not be explained on the assumption of an extension from a ruptured tendon sheath, although it is certain they are possible

Systemic Involvement —As a sequence of lymphangitis proper or associated with other types of infection of the hand, systemic involvement may be seen It occurs more frequently as the age increases While deaths may occur at any age, by far the greatest number occur after forty-five years, and after fifty years a severe infection of the hand should be looked upon with anxiety In almost all of the fatal cases I have seen there had been ill-advised incisions In many of these I believe the death could be attributed directly to this surgical interference It occurs most often associated with a streptococcus infection In one case, however, that died under my care, a staphylococcus was present in the pus of the primary abscess (Case IX) Every case showing evidence of

septicemia should be regarded as extremely grave. Early in the course it may be impossible to differentiate a septicemia from a toxemia, since they will present the same picture at the onset. The temperature is often 103° to 106° F., the pulse, 120 to 130. The dry tongue and skin, the restless, roving eyes, the constantly moving limbs, the thirst, scanty urine, headache, sleeplessness, flushed cheek, damp brow, and the quivering nostril, with the history of chilly feelings or a chill, present a picture known to all, and early may be present in either a toxemia or a septicemia. In a toxemia, however, all these symptoms should subside within three days if due to a primary unopened lymphangitis, or if it follows the opening of an abscess or a tenosynovitis. If, instead of subsiding, the symptoms grow more severe, it is probable a systemic infection is present if the local pockets of infection have been drained. The temperature generally continues high until death, but may become remittent, showing chills from time to time or symptoms and signs incident to complications, such as bronchitis, pneumonia, pleurisy, lung abscess, metastatic abscesses, and tenosynovitis, especially of the extensor tendon of the great toe, in my experience. The eye muscles may become paralyzed (Tornier). Almost all cases die when these severe symptoms develop. Death comes on with the patient in coma or delirium. Should the patient recover, the evidences of toxemia gradually subside and the local wound begins to show evidence of repair. The condition of the local wound as to repair is of considerable prognostic importance. When a wound does not heal as rapidly as it should after opening, exceptional care as to the systemic treatment should be used.

A fatal case of septicemia following a simple middle palmar abscess which had been undiagnosticated was referred to me and is worth reporting, since it illustrates the picture in the septic cases.

CASE IX —Mr R K, aged sixty-five years, admitted to the hospital January 23, 1909 Died, February 1, 1909

The history as recorded is very meager He stated that he hurt his hand rubbing meat and getting some brine in the scratches about a month previous to entrance, December 22, 1908 Following this his hand became swollen and painful Several incisions had been made on the dorsum On examination the right hand was found to be swollen, with the palm bulging The fingers were slightly restricted in motion There was little restriction of motion at the wrist, and little swelling of the forearm Systemically the patient showed the results of toxemia, being pale, weak, and emaciated, with the hunted look characteristic of these cases The urine showed a specific gravity of 1 020, was scanty in amount, but contained no albumin. There were, however, many hyaline and granular casts, both broad and narrow A diagnosis of a middle palmar abscess was made, associated with a toxemia of a high grade, or sepsis, and in addition a nephritis

In view of these findings and the man's age, a poor prognosis was given Operation Under nitrous oxide anesthesia, a Bier constrictor was applied and about one-half pint of thick, creamy pus was evacuated from the middle palmar space There was no pus in the thenar space or the tendon sheaths

Following the operation the temperature varied from 99° to 101° F, pulse, 84 to 100 During the second day it is noted on the history sheet "Patient removed Bier constrictor during night, has involuntary urination Hand and forearm violently inflamed, arm not involved Am not sure whether mental symptoms are due to kidneys or hand"

That night the temperature rose to 102° F, but varied from this to normal during the next day The pulse averaged 100 During the fourth day the temperature varied from normal to 100° F The pulse was still not rapid, although the patient was delirious and there was evidently a metastatic infection in the tendon sheath of the extensor hallucis of right leg Operation, January 29, 1909 Incision in palm enlarged and incision on lateral surface of forearm to secure drainage Considerable pus evacuated Incision over right fibula near ankle and into tendon sheath of extensor hallucis Watery pus evacuated

The pulse and temperature ran about the same as before The highest pulse recorded is 120, and the highest temperature, 102° F The mental condition grew worse, and the patient died two days later

Another fatal case, which I saw in consultation with Dr. A B Eustace, to whom I am indebted for the history and report of the findings at postmortem, at which I was

permitted to be present through the courtesy of Dr. W. H. Hunter and Dr. Eustace, is a very valuable one, since the positions of pus shown at the postmortem fully corroborate the findings which I have noted clinically in the cases which recovered, as well as verify the results which I obtained experimentally by injections of the forearm. It emphasizes also the difficulty of differentiating these cases at times from rheumatism. Unfortunately, I have not the exact age, but the patient was in the neighborhood of fifty years, which again draws attention to the influence of age in these fatalities

Here the primary focus was in the ulnar bursa. Owing to the difficulty of diagnosis, the diagnosis and, consequently, the proper treatment were held in abeyance several days

CASE X —Miss E J , Cook County Hospital. Patient entered on June 1, 1908 Attending surgeon, Dr E Wyllys Andrews, house physicians, Drs Eustace and Courtenay

History of Present Trouble Patient enters hospital complaining of pain and swelling in right wrist and hand Upon questioning she says she awoke last Friday night with pain in this joint There was a sense of heat and the joint was particularly painful on motion Her sleep was disturbed, and by the next morning she says her wrist was notably swollen and red Tenderness was pronounced over the end of the ulna posteriorly, and also anteriorly over both bones of the forearm at their carpal articulation

A history of any previous injury, fall, infection, or arthritis of any sort is denied The patient also denies other symptoms of any sort, but since Friday the joint has become swollen and progressively worse, the pain is agonizing, and there is an indefinite history of chills and fever

Previous Illnesses For the past ten years she has suffered intermittently from articular rheumatism, and three weeks ago she was a patient in this institution for otitis media and discharged after a period of two weeks' treatment

Physical Examination Negative except as follows· The right wrist and hand are greatly swollen and inflamed, the wrist on both surfaces, the hand on the posterior surface only The swelling is localized to the wrist-joint and extends up the forearm for about 3 inches The fingers are in semiflexion, and the slightest movement causes extreme pain There is also extreme tenderness around

the wrist-joint, which is also very painful upon motion Lymphatic involvement is lacking, and apparently there is no tendon-sheath involvement No atrium of infection can be found, and shoulder and elbow-joints are not involved. The left arm is not involved, though some pain is elicited on motion of shoulder. Fingers give evidence of a rheumatic diathesis (G. T Courtenay)

	Pulse	Temperature	Respirations
June 2, 1908 .	94	102° F	24
June 2, 1908 .	103	102° F	24
June 2, 1908 .	104	101° F	22

White blood count on entrance, 8200. Patient given large doses of sodium salicylate

Operation, June 4, 1908. Incision down to ulnar bursa and one above the transverse carpal ligament on ulnar side. A hemostat was forced through to the radial side and pus evacuated Gauze drainage and hot boric dressings Bier's constrictor applied to arm (A B. Eustace)

Operation, June 7, 1908 Two incisions on the flexor surface of the forearm just above the wrist-joint and another 3 inches above this These were each 1 inch long and penetrated to the flexor tendons, openings connected with gauze drainage (G T Courtenay)

Operation, June 15, 1908 Incision along ulnar bursa enlarged and a large amount of pus evacuated Knee-joint aspirated and pus obtained Two per cent solution of formalin in glycerin injected Died, June 16, 1908 Autopsy by Dr A B Eustace and Dr Allen B Kanavel

Hand and Arm Extensor surface On opening back of forearm a small focus of pus is found at junction of lower quarters of forearm This communicates with incision in skin on side There was no pus between extensor communis and deeper tissues, except at point indicated, and this pus extended down underneath this muscle

No pus found subcutaneously on the dorsum of the hand except at the wrist-joint, and this could be traced into the tendon sheath of the extensor digitorum communis The tendon sheaths of the extensor radialis longus and brevis also showed pus The tendon of the extensor carpi ulnaris was free from pus

Back of the sheath of the extensor digitorum communis is seen an opening extending down to the carpal bones Articulation between the carpal bones and the radius found to contain a slight amount of pus Articulation between proximal and distal row of bones also contains a slight amount of pus No pus found under tendons on the back of the hand, communicating with joint

Flexor Surface Incision found in median line, at junction of lower and middle thirds through skin immediately above transverse carpal ligament, and on either side at and above articular surface.

Incision on ulnar side extended upward for a distance of $2\frac{1}{2}$ inches Incision also in palm of hand on ulnar side lengthwise along inner edge of hypothenar eminence The hand as a whole does not appear to be greatly swollen, and some concavity appears in the middle of the palm

Upon opening the palm of the hand, ulnar bursa found to be filled with pus and tendon sheath of little finger also filled with pus Rupture had occurred into the forearm at a point $1\frac{1}{2}$ inches above the articular surface of the wrist-joint Middle palmar space opened and found to be filled with pus Thenar space free from pus Tendon sheath of flexor pollicis longus free from pus Radial bursa, no pus found at any point Above the wrist-joint, pus is found in sheath passing up underneath tendons from mid-palmar space

Forearm Pus is found underneath the flexor digitorum profundus Pus extended up the forearm in juxtaposition to ulna up to the elbow lying immediately on the ulnar

Pus also found along ulnar artery for a distance of about $1\frac{1}{2}$ inches at middle of forearm, but did not extend up to the elbow A small opening is discernible at lower end of ulna connecting joint with ulnar bursa It could not be determined definitely whether this opening was made by dissection or was present before

No opening was demonstrable between wrist-joint and radial bursa.

No necrosis of bones of wrist-joint, tendon sheath of ring finger intact, tendon sheath of middle finger intact, tendon sheath of index finger intact Pus extended out in little finger to proximal interphalangeal joint Periosteum of radius and ulna not destroyed No pus in elbow-joint Axillary glands barely palpable

Heart No evidence of pericarditis or adhesions

Pleural Cavities Left, no adhesions, right, few adhesions at apex.

Lungs Left, crepitates, no consolidation, frothy red serum exudes, apparently normal, right, answers above description

Liver Gall-bladder distended and filled with fluid Liver is mottled on cut sections, the interlobular markings faint, no evidence of miliary abscesses Tissues very soft and friable and color is paler than normal

Spleen Enlarged in size, is soft and friable Cuts like butter Miliary abscesses found.

Kidneys Soft and friable Capsules strip with some difficulty and leave parts of the cortex Cortex is almost obliterated, as are also the pyramids, but here and there a distinct outline of a pyramid may be found

Right Knee-joint Filled with thick yellow pus, small ecchymotic areas in periosteum

Cultures before and after death showed Staphylococcus albus

Microscopic examination of the various organs showed acute parenchymatous degeneration

POSTMORTEM STATISTICS.—Tournier reports 10 fatal cases upon which postmortem had been made. The findings were as follows:

	Cases
Acute hyperplasia of spleen .	9
Parenchymatous nephritis .	7
Bronchopneumonia	5
Lung abscesses .	2
Empyema .	2
Acute pericarditis .	1
Hemorrhagic pleuritis	1
Subpericardial, subpleural and cecal hemorrhages	4
Abscess of kidney . . .	2
Abscess of liver	2
Thrombosis of veins . . .	2
Icterus . . .	3

The age of the fatal cases averaged forty-three and eight-tenths years.

THROMBOPHLEBITIS.—Either associated with lymphangitis or as a distinct process we may have thrombophlebitis The symptoms and signs here would be the same as those occurring with thrombophlebitis of the leg, where it is more common Generally beginning with a localized infection, the process extends into a vein. The severity of the symptoms depends upon the extent of the process, varying from those of a mild septicemia with localized evidences to most severe toxemia, metastatic abscesses, and death. This can best be illustrated by a case which came under my care at the Post-Graduate Hospital.

CASE XI.—Mr L, aged twenty-five years Post-Graduate Hospital, March 5, 1909 (Fig 112)

Diagnosis—Suppurative phlebitis of veins of dorsum of hand

The patient applied to the hospital with a small infection upon the dorsum of the hand, apparently carbuncular in nature The infection had been present for four days, and was gradually increasing in size The hand was considerably swollen, and there was an area of swelling and induration extending up the dorsum of the forearm for 3 inches Temperature, 101° F, pulse, 94, urine negative.

Operation—Gas anesthesia A crucial incision was made over the area and an accumulation of thick pus and seminecrotic tissue

evacuated The indurated area extending up the dorsum of the forearm was found to be a large vein which was filled with a septic thrombus This was opened up for 4 inches on the area, when a free regurgitation of venous blood was secured The vessel was tied and the wound left open (Fig 112) A Bier constrictor was applied

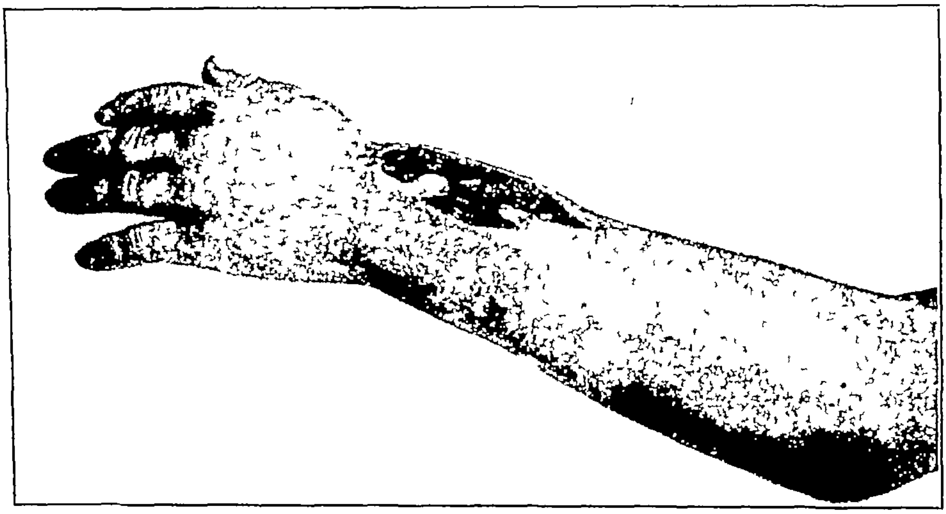


FIG 112 —Photograph of a hand of a patient with thrombophlebitis Wound is left open, as is seen in photograph (Case XI)

Following the operation the local area granulated freely, and rapidly went on to complete repair. Over a period of four weeks, however, the patient developed three metastatic abscesses in various parts of the body, which were opened Fortunately, none developed in the bones or viscera, at least so far as was discovered The temperature and pulse were never high, but still fluctuated with the development of the foci. The patient ultimately made a complete recovery.

PROGNOSIS IN LYMPHATIC INFECTIONS

The prognosis as to life in lymphatic infections is dependent upon so many factors over which we have no control that it is extremely difficult to arrive at any satisfactory statement concerning it In Helferich's Clinic, in a series of nearly 200 severe infections of the hand, a fatal issue followed in 22 per cent These statistics comprise all types of infection of the hand, and are

limited to extensive abscesses, tenosynovitis, and severe lymphangitis. This percentage is certainly high for patients in the ordinary walks of life. In my own experience the mortality in these severe cases will average less than 3 or 4 per cent.

Of the factors concerned, of chief importance is the age of the individual. The average age of fatal cases is in the neighborhood for forty-five years. The general state of the patient's resistance is of importance For instance, in Cook County Hospital, where the social derelicts are found, the mortality is much higher than in private hospitals The presence of nephritis in the various forms or of any of the chronic system diseases has a marked influence upon the prognosis

If the symptoms of toxemia do not subside within three days, if no local process has developed, or within two days after opening such foci, anxiety should be felt for the patient Either there is a local extension, or the patient is not reacting The part affected has some influence upon the prognosis The presence of an infection beginning in the little finger or the thumb causes fear of tenosynovitis with a prolonged convalescence, while an involvement of the index or middle finger may early lead to severe systemic symptoms. The type of germ in a given patient is also of great importance from a prognostic standpoint, since it is well known that the gravest infections arise from the streptococcus and certain of the gas bacilli Again, a brusque onset with high temperature and chills speaks for a serious infection

To my mind the prognosis is influenced somewhat by the character of treatment *If ill-advised and premature incisions are made what might have been a moderate infection may be turned into a severe type*

What may be said regarding the probability of local complications? It is impossible to arrive at any just estimation as to the probability of the development of

tenosynovitis and fascial-space abscesses In my experience those patients showing a brusque onset with great pain are more likely to have such complications The tenosynovitis is more likely to develop from infection implanted on the volar surface of the distal or middle phalanx Local accumulations on the dorsum of the web between the fingers are apt to develop from the callus cracks at the distal portion of the palm Dorsal subcutaneous thenar abscesses appear in infections of the thenar palmar surface. Subcutaneous abscesses above the anterior annular ligament often occur in connection with tenosynovitis Ill-advised incision may determine the localization of infection in various spaces In several patients whom I have seen in consultation, I felt sure that the tenosynovitis which developed was directly due to the primary incision

RÉSUMÉ

The symptoms and signs appear as follows Red lines running up the forearm corresponding to the anatomical distribution of the lymphatic vessels draining the area of primary infection There may be no local reaction and little swelling, generally, however, there is slight swelling accompanied by dull pain In the less severe cases considerable edema will develop on the dorsum and the pain will be very severe Early there is little tenderness Generally, after twenty-four hours, tenderness may develop in the extremity over the glands involved, *i e*, the epitrochlear or axillary

Systemic symptoms vary in the widest limits In some cases very early the patient presents evidences of severe toxemia, with a chill, high or low temperature, headache, anorexia, and prostration Four types are seen A, simple acute lymphangitis This is a type with few systemic symptoms and a rapid disappearance of lymphatic inflammation B, acute lymphangitis with minor local complications: Here the symptoms subside

slowly, ending in an abscess at the site of inoculation or in the gland area. C, acute lymphangitis with serious local complications: Here we have such complications as tenosynovitis and subcutaneous phlegmons. D, acute lymphangitis with systemic involvement: In this group we have the most alarming systemic symptoms with little local evidence of disease and at times a rapidly fatal issue.

Phlegmonous lymphangitis is one of the most serious types of infection seen Here we have profound toxemia, a greatly swollen forearm, board-like indurations and blisters on the skin. The subcutaneous tissues sloughs *en masse*. The superficial veins become thrombosed and the patient dies from toxemia or some of the severer complications of infection, such as sepsis, meningitis, pneumonia, etc. (See "Gangrenous Infections.")

Localization takes place in lymphangitis in from 10 to 15 per cent of the cases The sites are ordinarily the tendon sheaths, dorsum of the hand, the dorsum of the forearm, the epitrochlear region, and the axilla.

Systemic infection is more likely to occur in individuals over thirty-five years of age and is more likely to follow infections of the thumb, index or little fingers, especially the middle finger It frequently follows ill-advised incisions In these cases the onset is brusque, there is little local reaction along the lymphatic or glandular region, prostration becomes profound, and death rapidly ensues

Deep lymphangitis is on the whole rather a rare complication. If present, the pus is found in the deeper portions in the pockets already enumerated

Thrombophlebitis may occur associated with lymphangitis or as a distinct process

The mortality is not high unless ill-advised incisions have been made.

CHAPTER XVIII

THE TREATMENT OF LYMPHATIC INFECTIONS AND THEIR COMPLICATIONS

THE treatment of lymphatic infections is based upon two principles—conservatism and conservation *In no type can more harm be done by ill-advised incisions than in this.* The position of masterful inactivity is most difficult to maintain, and yet the surgeon is constantly aware that his tendency to incise is due to his desire "to do something" rather than an exact knowledge as to what to do We therefore use local measures designed to wall off and overcome the infection, combined with procedures designed to support the system and increase its resisting powers and eliminate the toxin In the ordinary case, until some localization is present, we apply hot, moist dressings, insist upon local and systemic rest, combined with cathartics, much fluid intake and sedatives, as the case may demand

DISCUSSION OF VARIOUS PROCEDURES

LOCAL —*Hot, Moist Dressings* —Many forms of such applications are in use and have a vogue for a time. It is my personal opinion that such applications owe their value more to the moist heat than to the drug with which they are combined It is my custom to use boric acid in saturated solution I am aware that many studies have been made from which conclusions were drawn as to its antiseptic property when absorbed by the blood stream It is probable that it would be unjust to say that such minute quantities as have been demonstrated in the blood, and consequently in the urine, can have no effect, since no one knows the effect of combining small

proportions of any chemical solution with blood serum *in vivo*, although in the test-tube such combinations may be shown to be without value. It would seem more reasonable to ascribe the beneficial value of such applications to the dilatation of the capillaries and the bringing of more blood to the part, favoring the walling-off of the infection.

Peculiar value has been ascribed by various surgeons to bichloride solution, creolin, almost all of the various antiseptics, ichthyol, alcohol, etc. Unless they are used for a particular purpose, however, it would seem that hot boric acid solution will be as efficient as any.

Certain special purposes may be secured by special solutions. In those cases in which there is a foul odor, a 1 to 2000 or 1 to 4000 potassium permanganate solution will be found of value. We may secure some slight local antiseptic property in the use of alcohol dressings, using a 30 to 50 per cent solution This should not be kept up any length of time. It is certainly not necessary to warn the profession against the use of carbolic acid solution in any strength. The frequency with which carbolic acid gangrene is seen, however, leads me to urge upon physicians the necessity of informing patients of the danger of this remedy, which is so often the home application for all cuts and injuries

The method of applying hot boric dressings has been discussed in Chapter VIII They are so applied as to cover the entire arm to the shoulder in the severe cases It is a good rule to make the dressing much larger than the condition would seem to call for. These hot, moist dressings are to be used until the red line of lymphatic involvement has entirely disappeared and any acute edema has begun to subside, at which time a change should be made to a dry dressing of some kind

Rest.—Both local and systemic rest should be insisted upon, especially in severe infections Immobilization is

of special value in a prophylactic sense, since every movement of the fingers or hand tends to favor lymphatic circulation and hence to favor dissemination of the infection Von Volkmann and others have advised suspending the arm so that the hand is elevated It does not seem that this would be of value except to relieve the pain of a congestion

The Bier Treatment —The place of the Bier treatment in infections of the hand has already been touched upon In lymphatic infections I have used it only in the same sense that we would use a ligature to prevent the rapid absorption of any poison, as, for instance, in the slow absorption permitted in snake bites It therefore would find a place in the early hours of a virulent lymphatic infection in which the system may be receiving large doses of virulent toxins without seeming to have the reactive power necessary to wall-off the infection Here the constrictor is applied for from twelve to eighteen hours, only tight enough to secure an edema This is done with the hope that the lack of reaction upon the part of the system is due in part to the fact that it is overwhelmed, and that if small doses are allowed to enter the system an antitoxin will be developed which will be able to overcome the toxin if its entrance into the system is spread over some time Whether or not diapedesis of leukocytes in these infections is favored by passive congestion is a moot question

The method of applying the bandage is as follows:

A Martin bandage 2 inches wide is used The bandage is begun at a point slightly above the elbow and carried to a point slightly below the axilla Several turns are carried about the arm, so made as to preserve an equable pressure throughout The pressure should be sufficient to produce a moderate edema in an hour, and should not be sufficient to produce pain It should be examined repeatedly to be certain greater pressure does not develop

The method used by some of wrapping a towel about the arm and securing constriction by a rubber tube or narrow rubber band is unwise, since it will cause considerable pain and is more likely to produce nerve injury. After the bandage has been in place twelve to eighteen hours it is removed and replaced in a couple of hours if the toxemia is still high. Ordinarily, one or two eighteen-hour periods is all I have found of advantage in these cases In later years I have used an ordinary blood-pressure apparatus filling the arm band with air up to the desired pressure.

Incisions —There may be some difference in opinion as to the advisability of incisions under certain conditions In my judgement, however, no incision should be made, except in the presence of frank abscess formation.

There are those who believe that an incision made at the point of great pain and tenderness when it is the site of the primary infection will be of value They maintain that such an incision, if it does not evacuate pus, favors drainage about the site of the infection, and that the escaping serum carries off the bacteria It is my own belief that this hope is not justified, and that the incision simply opens new lymphatics for infection and fails to reach the bacteria which have already entered the lymphatic stream and are multiplying some distance from the site of entrance Therefore the prophylactic incision fails of its purpose and will do much harm by producing complications

Shall incisions be made along the line of lymphatics? In those cases in which there is one or possibly two red lines of lymphatic involvement running up the arm, some surgeons have advised that a transverse incision through the skin and subcutaneous tissue should be made, so as to prevent the channel from carrying more toxin. I am convinced, however, that the procedure does more harm than good, since it pours out into the wound the

virulent bacteria and toxins which at the end of a few hours begin to be absorbed in greater amount than before The picture presented by this procedure is very characteristic Within an hour after the cut is made the part proximal to the incision becomes pale, the red lymphatic disappears, and the surgeon feels that his procedure has been justified by the results At the end of a few hours, however, it is seen that the portion distal to the incision has begun to assume a reddish tinge, and shortly a considerable area takes on the characteristic appearance of an erysipelas, with an aggravation of the symptoms.

In other instances the little lacunæ found in the course of the lymphatic vessels (see p 104) show small areas the size of a bean in the course of the lymphatics, at which sites there is a local swelling and edema These are most common on the dorsum of the hand The thoughtless are inclined to incise these under the impression that localization will be found there and that drainage is indicated If incision is made, however, only a small amount of serum will exude, and in the severe cases the procedure is generally followed by a chill and rise of fever within an hour or two, sometimes to an alarming degree, while the procedure is detrimental rather than beneficial to the ultimate course

If incision is made in these cases for any cause, the possibility of spreading the infection must be borne in mind and one should seek at least to prevent rapid absorption This is done by keeping the arm absolutely at rest and applying a Bier constrictor to the arm This should be left on for from twelve to eighteen hours. These incisions will be called for in those cases in which localization in the tendon sheaths or in the subcutaneous tissues has taken place, as, for instance, on the back of the forearm or about the glands.

SYSTEMIC TREATMENT.—*Antagonistic Drugs.*—Various drugs have been vaunted from time to time as of excep-

tional value in septic conditions. They may be classified as those designed to destroy bacteria and those to neutralize the toxin The value of any of them is questionable Quinine has been used for many years, and if it were of marked value sufficient positive evidence should have accumulated by this time to leave no doubt, and this cannot be said to be true The same may be said of urotropin and the various silver salts and dyes which have been vaunted so highly, and in my judgment the various injections of antiseptics into the blood stream Upon none of these can the surgeon depend with any distinct hope that they will be of value. The use of whisky is in a different class Any value it may have depends upon the fact that its elements are less stable than normal cell protoplasm, and consequently there is some hope that the toxin may unite with these rather than cause destruction of the living cells There may be some truth in this The trouble is that to be of much value in this regard there should be a considerable amount in the blood, and the excretion of any considerable amount would be injurious to the kidneys.

Food and Fluids—I am accustomed to give those patients who are seriously ill small amounts of easily digested food frequently or peptonized food per rectum if they cannot take it by mouth, so as to introduce into the blood peptones, less stable than normal albumin of the living cells, with the hope that the toxins will unite with the less stable combinations and thus protect the system This can do no harm, and may do good

It is imperative that patients should be given large amounts of water or fluids by mouth supplemented by plain water or normal salt solution by rectum In serious cases the normal salt may be given intravenously It is not given subcutaneously because of the liability of producing at the site of the injection secondary infection from bacteria floating in the circulation It is my belief

that the introduction of large amounts of fluid with the idea of diluting and eliminating the toxins is of great value.

Glucose and Blood Transfusion —Glucose should be administered intravenously in severe cases supplemented by repeated blood transfusions.

Serum and Vaccine Treatment.—We have not as yet developed any serum or vaccine that can be said to be of definite value in these acute cases The field is a most engaging one, and many attempts have been made to produce an antitoxin. The difficulties seem to be almost insuperable If given very early it might have some effect, since some of the sera, such as that of Aronsen, have some bactericidal action in addition to their antitoxic and opsonizing effect Often the toxemia is well advanced, and such an immense amount of antitoxin would be necessary to neutralize the toxins that we cannot hope to inject it, and the opsonizing and bactericidal effects are insufficient. Moreover, it has been shown many times that the antitoxin prepared for one type of streptococcus will have no effect upon the toxins generated by other types of streptococci.

Van de Velde showed that the leukocidin produced by one Staphylococcus pyogenes aureus might be almost innocuous, while another might be most virulent Denys, Van de Velde, Neisser, and Wechberg have produced antileukocidin, but it must be for the specific organism.

Therefore, to secure the best results a serum must be made from the germ producing the disease, and this is manifestly impossible, since the time is too short In emergencies stock antiserum of the same type may be used In attempts to obviate this difficulty some have made their antistreptococcus serum from a combination of several strains of streptococci, *i e.*, the so-called polyvalent antistreptococcus sera, such as those of Tavel, Moser, Menser and others, while the sera of Marmorek

and others is monovalent, *i e.*, made from one strain Whether these sera act in a bactericidal or antitoxic manner or by stimulating cellular activity is a subject for discussion, but at least the effect is inadequate It is possible that in the more chronic types vaccines may be produced that will aid somewhat. In this connection a perusal of Case XIII should be of interest. In this case almost all of these methods were tried without avail.

In spite of the lack of conclusive results by any of these methods, one cannot but hope that the future holds some promise of aid from these studies The surgeon should always have in mind the possibility of value from the administration of sera, watching his patients closely for a favorable opportunity. As the case now stands I fear that he is not in position to promise his patients any distinct curative action in the more acute cases I would not state this dogmatically since some able investigators disagree with this opinion. For instance Jopson and Eiman believe that in hemolytic streptococcic septicemia polyvalent antistreptococcic serum is of value especially if administered early and in sufficient quantities (100 to 750 cc) intravenously. They differentiate two types, "shower" and "massive." In the former positive blood cultures on blood agar plates obtained after opening a primary acute focus show but few colonies of organisms In such cases the natural resistance of the patient will usually destroy the organisms In the latter hundreds of colonies are secured per cubic centimeter of blood Under these conditions the natural defense of the patient is rapidly exhausted. Their table summarizes 43 cases of bacteriemia Twenty-four received no serum or less than 100 cc Five recovered and 19 died Nineteen received adequate amounts of serum, 15 recovered and 4 died. All the 15 in this group presented the "massive" type of infection This is certainly encouraging and justifies the surgeon in the use of large amounts of such serum

Allied to this we have the treatment of streptococcic septicemia by specific and non-specific immunotransfusions The methods of application vary but ordinarily in the first method a donor's blood is built up to resist the specific organism by repeated injections of dead identical organism and in the second by a single injection of dead typhoid bacilli Ordinarily 250 cc of the immunized blood is transfused at intervals. These methods are still too much in the experimental stage to justify extensive discussion, although some favorable results have been reported

Systemic diseases such as diabetes, syphilis, and nephritis should be sought for and, if present, appropriately treated

Supportive Measures.—Supportive measures in the way of stimulants, fresh air, good food, attention to the bowels, and proper rest should not be neglected Fresh air and sunlight, especially in the more chronic cases, are of distinct value One patient suffering from such a chronic infection, which defied all manner of treatment, was transferred to an open-air sun room where he lived and slept The benefit of the change was evident to everyone (See Case XIII)

THE TREATMENT OF THE COMPLICATIONS OF LYMPHANGITIS

Tenosynovitis

Attention has been drawn to the frequency of tenosynovitis in lymphatic infections beginning in the distal phalanges on the volar surface. In the chapter dealing with the subject of tendon-sheath infections a complete discussion is given which should enable the student to diagnosticate the presence of such a complication, and rules have been laid down for the treatment that has been most successful in my hands

SUBCUTANEOUS ABSCESSES

Subcutaneous abscesses may appear upon the dorsum As soon as a definite redness and hardness have appeared, indicating pus, free incisions should be made. *Simple redness and edema are not sufficient to indicate incision,* but when the hardness has been added free incisions should be made. *If the condition of the patient will permit, it is wise to await complete walling off of the pus pocket before opening* The presence of extensive subcutaneous destruction of the connective tissue with the formation of a slough with streptococcus pus is one of the most serious complications. Incision should be made early, in several places upon the dorsum, so as to give perfect drainage At the risk of useless repetition, let me say again that I am speaking of the indurated, brawny, dark red dorsum, characteristic of the spreading virulent phlegmon, not of the pinkish, edematous, pitting dorsum. Neither am I speaking of the simple staphylococcus abscess. The gravity of this severe type has long been recognized (See "Gangrenous Infections")

The following case under the care of my associate, Dr. Koch, illustrates this type of infection.

CASE XII —Dr E B, admitted December 14, 1931

Entrance Note by Dr Koch —Oblique knife cut just distal to proximal interphalangeal joint on dorsum left little finger while performing an autopsy on case of bone sarcoma yesterday morning, December 13, 1931

Took glove and kept hand wet, continued autopsy for twenty minutes, then applied 80 per cent alcohol and a dressing which was taken off five hours later Got home at noon and then went to Michael Reese Hospital No pain until 9 30 P M, then local pain around cut Soaked hand in warm water in wash bowl for an hour Put on dressing saturated with hexyl-resorcinol

At 2 00 A M awoke "with a bang" Pain and swelling about site of injury Applied hot boric dressings at 4 00 A M Awoke again with pain Then noticed red streaks extending up forearm and arm At that time temperature was 103° F.

Examination by Dr Koch —Small $\frac{1}{4}$ inch cut on ulnar side of dorsum of left little finger a little distal to proximal interphalangeal joint. Cut oblique, making a short flap, with base proximalward.

A little sero-purulent discharge oozing from cut Finger swollen, particularly on dorsum Hand a little swollen

Red streaks on dorsum of forearm, irregular, not very distinct

Two distinct red streaks, $\frac{1}{8}$ inch wide, $\frac{3}{8}$ inch apart, extending straight upward to axilla along middle of medial aspect of arms No palpable glands Large hot wet sterile dressings

Progress Notes —December 15, 1931. Dr. Mason: Temperature 102 4° F at 8 00 A M Patient feels uncomfortable from abdominal pain which he says is not like the ulcer pain. Nausea and vomiting controlled by mucin

Chest shows no râles though some course bronchial sounds are present on right posterior Abdomen seems fairly firm but not rigid and not tender Hand dressed. Wound on V finger left looks subsiding, tenderness over dorsum metacarpals V and IV and over dorsum wrist No lymphatic streaks on arm or axilla Patient looks sick today.

December 16, 1931 Dr. Koch. Red streaks have disappeared from area No marked swelling of dorsum of hand or fore-arm. This is somewhat tender No evidence of localization Abdominal pain and discomfort less since he has begun treatment.

December 18, 1931 Dr Mason Temperature 101° F. Patient has been uncomfortable during the night Considerable redness over forearm and arm General swelling over dorsum wrist. No localization

December 20, 1931 Dr. Zellhoefer Dressing changed There is considerable redness of arm, but less than on December 19, 1931 The swelling of forearm is also somewhat reddened Pulse and temperature normal this morning

December 21, 1931 Dr Mason Hand still considerably swollen, over the dorsum—quite red up to midway between wrist and elbow. Edema of elbow No complaints

December 22, 1931 Dr Koch Area looks satisfactory. Redness and swelling have practically disappeared Forearm less swollen, less red Dorsum of hand still swollen, sense of fluctuation over dorsum of metacarpals Either edema which may gradually subside or slowly localizing abscess over dorsum of hand

December 23, 1931 Dr Koch Large blister on dorsum of hand with thick pus underneath When blister was lifted away a small opening was seen at above middle of dorsum of metacarpal from which this pus was exuding Culture taken Hot wet dressing which had been omitted for three days resumed

December 24, 1931 Dr. Koch Free drainage. Opening on

dorsum of hand larger, about 0 5 cm in diameter Some necrotic tissue removed from opening (Fig 113)

December 25, 1931 Dr Koch Chill this morning (10 00) Temperature 102° F No evidence of thrombophlebitis, but a little more swelling and redness of lower forearm, with suggestion of abscess formation there Considerable purulent drainage from dorsum of hand with one new opening ulnarward and distalward from original site of drainage

December 26, 1931 Dr Zellhoefer Patient appears much better today Temperature and pulse have dropped back to normal Tenderness in the upper arm and axilla has disappeared There is some redness and swelling over the pad on the palmar surface of the index metacarpo-phalangeal joint, but do not think it is due to extension of the infection Dressings changed and small amount of boric solution put on them Stomach and bowels normal this morning

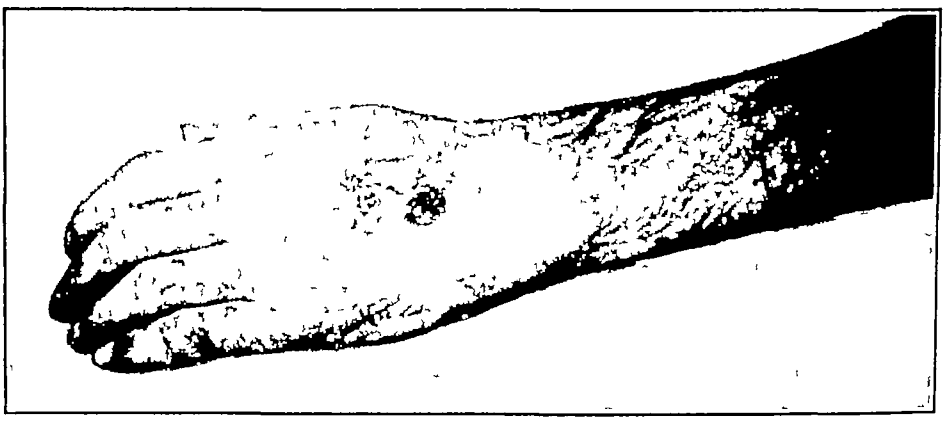


FIG 113 —Subcutaneous phlegmon following lymphangitis, Case XII

December 29, 1931 Dr Zellhoefer Patient is showing improvement daily Temperature and pulse have been normal now for the past three days Dressings changed this morning and wound looks satisfactory Redness in arm and forearm is slowly disappearing

December 24, 1931 Bacteriology Report Direct smear made from pus shows many Gram-positive cocci, many of which are in chains, a few in cluster There are many polymorphonuclear cells present and an occasional phagocyte containing cocci in chains

Cultures show a heavy growth of hemolytic streptococci and an occasional colony of staphylococci

January 3, 1932 Patient discharged, recovered

ERYSIPELAS

Erysipelas may appear in two types first, an uncomplicated cutaneous lymphangitis corresponding to the

picture seen upon the face, and, second, as a cutaneous lymphangitis, complicated by a subcutaneous lymphangitis This latter type is more common in the hand The former, the rarer type, is that of the typical erysipelas as seen upon the face with the brawny induration confined to the skin and outlined by a distinct border The deep purple-red skin may have blebs upon it The second type is the accompaniment of the severe subcutaneous lymphangitis Localized gangrene of the skin may appear in this latter type

The treatment of erysipelas proper is clearly that of a lymphangitis which has already been discussed No special applications, such as carbolic acid, ichthyol, salicylic acid, can be considered to be of special value In the superficial type the usual hot, moist dressings may be used, the treatment of the severer types referred to, which are often called gangrenous erysipelas or gangrenous cellulitis by surgeons, has been discussed when dealing with "Gangrenous Infections"

Periglandular Abscesses

Periglandular abscesses occur especially in the epitrochlear and axillary regions These are not so virulent as the type just described, and a more conservative course may be pursued Since they start from glandular suppuration, some days will elapse before they become evident The surgeon will often be in doubt for a day or two as to whether the infection may not be a simple glandular hyperplasia The waiting period is not without advantage to the patient, since it offers an opportunity for the abscess to become walled off and thus favor the prevention of extension when it is opened

Subpectoral Phlegmons

Attention should be drawn to the so-called subpectoral phlegmons These are in reality abscesses arising from

dorsum of hand larger, about 0 5 cm in diameter Some necrotic tissue removed from opening (Fig 113)

December 25, 1931 Dr Koch Chill this morning (10 00) Temperature 102° F No evidence of thrombophlebitis, but a little more swelling and redness of lower forearm, with suggestion of abscess formation there Considerable purulent drainage from dorsum of hand with one new opening ulnarward and distalward from original site of drainage

December 26, 1931 Dr Zellhoefer Patient appears much better today Temperature and pulse have dropped back to normal Tenderness in the upper arm and axilla has disappeared There is some redness and swelling over the pad on the palmar surface of the index metacarpo-phalangeal joint, but do not think it is due to extension of the infection Dressings changed and small amount of boric solution put on them Stomach and bowels normal this morning

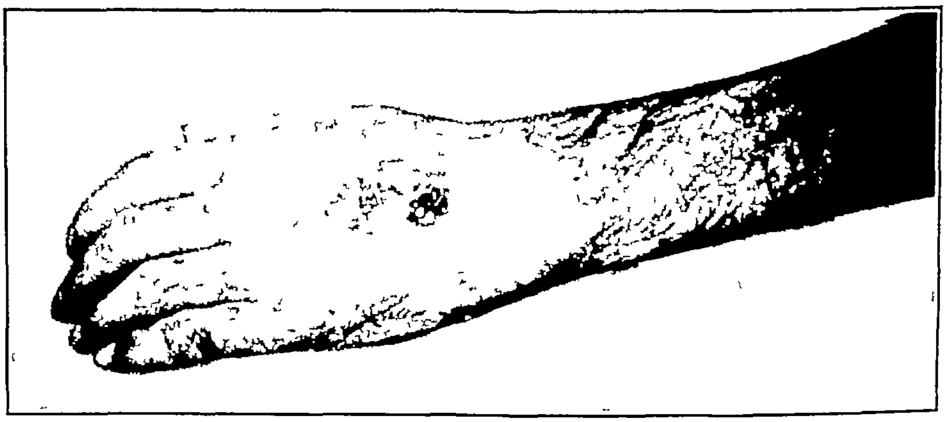


FIG 113 —Subcutaneous phlegmon following lymphangitis, Case XII

December 29, 1931 Dr Zellhoefer Patient is showing improvement daily Temperature and pulse have been normal now for the past three days Dressings changed this morning and wound looks satisfactory Redness in arm and forearm is slowly disappearing

December 24, 1931 Bacteriology Report Direct smear made from pus shows many Gram-positive cocci, many of which are in chains, a few in cluster There are many polymorphonuclear cells present and an occasional phagocyte containing cocci in chains

Cultures show a heavy growth of hemolytic streptococci and an occasional colony of staphylococci

January 3, 1932 Patient discharged, recovered

ERYSIPELAS

Erysipelas may appear in two types first, an uncomplicated cutaneous lymphangitis corresponding to the

Systemic Complications

These must be met as they arise and the treatment based upon the general surgical principles governing septicemia and pyemia. The metastatic abscesses should be opened, empyemas drained, pneumonia, etc., guarded against with every possible precaution

The question of amputation of the arm in these severe cases will be a constant one, but no definite rules can be laid down One will constantly feel in the early cases that amputation is too severe for the condition, and when systemic infection has begun it will be considered that amputation will be futile, so that the indications for amputation will be drawn between narrow lines. In exceptional cases some hope may be offered by this procedure, as, for instance, in a spreading phlegmon or in a malignant edema.

Chronic Infections. Repeated Infections

It is an unfortunate fact that one infection with the streptococcus does not immunize the patient; at least, if it does, it is only for a short time Not only are repeated infections possible, but one infection seems almost to favor a second at a later date This is not true to the same degree with the staphylococcus, by which a mild degree of immunization may be secured. This is demonstrated by the raising of the opsonic index as determined by the Wright method. The streptococcus particularly not only may not develop immunization, but also lacks to a marked degree the power in many cases to produce antitoxins in a degree sufficient to overcome itself, so that we often see cases of chronic long-continued infection which undoubtedly had their origin in a streptococcus infection No better example of this type of infection could be cited than that of a case I saw with

infected glands They have assumed some prominence in clinical surgery since, in addition to abscesses developing here from a frank infection of the hand, we not uncommonly have these abscesses develop from insignificant or unnoticed infections in the hand, as for instance, in one of our cases it developed after an impetigo had disappeared In other cases the patient presents the systemic picture of severe toxemia with little local evidence of infection about the axilla, due to the fact that the abscess is deeply seated under the pectoralis major muscle and axillary fascia For some days only an indefinite pain may be complained of in the shoulder region, with a hardly noticeable swelling in the axilla Upon operation the surgeon is amazed by the quantity of pus that has filled the axilla and extended under the pectoral and scapular muscles

Subclavicular and Shoulder Abscesses

The occurrence of such abscesses will of course be rare, since they arise in the course of the lymphatics lying in the pectoro-deltoid groove, having their origin most commonly in the middle finger It has been my fortune to meet with only one such case, and this began in the index finger Dr J M. Neff has seen and operated upon another one, in which the origin was in the middle finger, followed in three days by a subclavicular abscess, which was opened, and this in turn was followed or accompanied by a synovitis of a knee-joint of a serious nature, but from which the patient ultimately recovered This case then is most interesting, since it corroborates the statements I have made as to the origin of these abscesses from the middle finger and also serves to emphasize the seriousness and frequency of systemic involvement from lymphangitis originating in this digit

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Dr. Oleson has already reported the case, and I herewith abbreviate his report:

CASE XIII—"On June 15, 1906, over three years ago, the patient removed a wart from the index finger of his right hand, leaving an opening in the subcutaneous tissue which did not readily close While this condition existed he received orders to care for some sick calves, afflicted with a disease which caused dyspnea, with considerable salivation In giving them medicine it was necessary for him to introduce his right hand into their mouths, with the natural consequence that it became covered with their slobbery saliva In a few days he sickened and called in Dr William Dillon, of Urbana, who reports under date of August 18 substantially as follows

"'In regard to Mr J's illness, I was called to his room about 9 P M, June 27 I found him lying down, with perspiration in large drops over his face, pulse full and rapid, temperature about 103° F Pain about axilla Axillary glands indurated and enlarged There was a small unhealed place in the center of a spot on one of his right fingers, from which I could press out a little serum, but which had no soreness I ordered fomentation during the night, with magnesia sulphate internally The following morning there was less pain, but more fever, and I had him removed to a hospital, where the treatment was continued The glands returned to their normal size so far as could be detected, but fever and sweating continued About the third day in the hospital painful tympanites developed, also swelling along the general direction of the pectoralis tendon from a little *below the arm-pit to near the eleventh rib This was the first appearance of localization* I called Dr Newcomb, who aseptically incised the tissues down through the deep fascia A little serum escaped About July 22 the second incision was made and the entire cavity washed out with bichloride and dressed with dry dressings Now the patient rapidly improved and the abscess walls united so that when irrigated the fluid would extend but a

short distance in any direction The pus by July 30 had almost ceased Temperature normal, pulse normal, patient bright, no sweating'"

Dr Oleson here continues

"I first saw the patient on August 10 On entering my office a limitation of motion in the right shoulder and a marked cervical scoliosis was evident He was pale, anemic, pulse, 106, temperature, 98° F At the anterior margin of the right axilla, along the border of the pectoralis major appeared a long scar, presenting at its upper end a small orifice discharging a thin blue-green serum A second opening existed to the axillary side of the scar, about an inch below the first sinus No swelling, some redness, tenderness slight, shoulder-joint motion limited, evidently from scar contraction A flexible sterilized probe introduced into the sinus with strict asepsis passed under the clavicle for some distance toward the vertebræ, so that the general clinical picture simulated a cervical Pott's But a few days' study satisfied me that there was no vertebral disease, nor could I find evidence of any shoulder-joint trouble

"He passed into the hands of a neighboring sectarian practitioner, and after some weeks of unimprovement entered a homeopathic hospital in this city Here the gradually enlarging ulcer, which appeared at the site of the sinus and slowly spread downward along the thoracic wall in the direction of the original incision was curetted, and the patient received considerable roentgen-ray treatment, with a steady failure of his vital forces until the latter part of March, of the following year, some nine months after the original infections, when, on the suggestion of the hospital authorities, he was taken from the institution to end his days among his friends Here I saw him on March 28, since which time he has been continuously under my care He presented then the typical picture of advanced chronic sepsis He was thin, haggard, with a marked Hippocratic facies, scoliosis more evident, temperature running a classical hectic curve (morning remissions to 98° F, evening readings varying around 102° F) The pulse constantly between 120 and 130, having the appearance of impending death Locally the margins of the sinus had broken down to form along the thoracic wall a deep ragged ulcer as large as the palm of one's hand with sinuses radiating upward, forward and downward, honeycombing the tissues in the pectoral region, while over the third and fourth right costochondral junctions appeared bluish-red depressed areas, evidently marking points at which pus was about to appear The former bluish-green discharge was now almost colorless, very profuse, and of a thin serous nature, soaking large gauze dressings daily

"On April 6, under chloroform anesthesia by Dr Pickard, with D W F Scott assisting me, I removed inflamed periosteum and perichondrium, with subjacent necrotic tissue at the points indicated by the discolored skin, curetting from all accessible places the

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paste method. Injections were given January 22 and 28, with no special result except that the patient's weight fell off a little. In order to give the paste a little better chance, I decided to curette the granulations from the sinuses again, and then to make a third injection. This I did on February 10, and on the morning of February 11, I found my patient with a pulse of 140, temperature, 102° F., rusty sputum and consolidation of the left lower lobe. A typical crisis occurred on the seventh day, with uncomplicated convalescence. One peculiar phenomenon presented itself on the third morning of the seizure, when the patient suddenly expectorated a single mouthful of pure pus, of which the anatomical origin was never satisfactorily located.

"On February 26, he returned to his home having lost 17 pounds, which he proceeded to regain. At this time, through the courtesy of Professor Ormsby, I secured from the research laboratory of Parke, Davis & Co., a supply of staphylococcus vaccine, varying doses being injected on March 14, and for a month afterward, without effect. Thorough search was now made by Professor Ormsby for evidences of blastomycosis, actinomycosis, and tuberculosis, with negative results. Professor Hektoen now generously placed at my disposal his laboratory facilities, and his assistant, Dr. D. J. Davis, readily isolated from the pus a streptococcus which grew abundantly in almost pure cultures, but presented no identifying morphological characteristics. The patient's opsonic index to this organism was subnormal.

"On April 16, I injected the dead bodies of 500,000,000 *autogenous cocci* obliquely into the subcutaneous tissue of the right thigh. In two days an induration appeared at the site of injection. Twelve days from date of puncture fluctuation was evident at this point. On May 6, twenty days from the injection, the skin grew purplish. Two days afterward, on May 8, under aseptic precautions, I aspirated some of the contents of the swelling, which, on examination by Dr. Davis, proved to be sterile, chemical pus. On May 15, twenty-nine days after injection, the skin finally broke down and the contents escaped, leaving a superficial ulcerated area, which slowly cicatrized across from the margins, ultimately healing on July 3, seventy-eight days after the date of injection.

"The history is that of each inoculation made obliquely, leaving the vaccine in the subcutaneous tissue. As time went on I lessened the dose to 250,000,000, 60,000,000, 10,000,000, and each one caused the breaking down of connective tissue, the formation of sterile chemical pus, the death of the overlying skin from starvation—an open ulcer—slow healing, so that we finally had an absolute clinical demonstration of the method of local spread of this coccus, namely, by the secretion of toxins, which by their chemical action on the connective tissue—not skin, not muscles, but subcutaneous tissue, fasciæ, septa, etc.—cause this to gradually die and melt away,

various sinuses, scraping out large quantities of soft, pale, pulpy, friable granulations, with free hemorrhage easily checked by pressure The patient was put to bed in an exhausted condition, while my consultants cheerfully foretold an early lethal termination

"On May 6, I performed a second similar operation, attacking new fresh necrotic areas over the second and fifth costochondral junctions The result of these two operations was a considerable improvement in the pulse curve, which now rarely went over 110, while the temperature did not pass above 101° F, with no local change except the healing of one sinus which had invaded the tissues from the lower margin of the ulcer.

"On July 6, I performed what was intended for a radical operation, by making a deep curved incision from the lower border of the ulcer, anteriorly to the sternum, separating the entire pectoral flap of muscles, reflecting them back over the shoulder and exposing this region for general curettage

"After thorough scrapings of all other lesions the flap of muscle was sutured back into place The patient did not react well, it being several days before he ceased vomiting, and the general immediate result of this intervention was the actual spread of the infection, as it followed each suture and needle puncture into new regions, reaching around also into the intermuscular septa and subcutaneous tissue of the back, a region previously uninvaded Various abscesses were opened during the next month

"During all this time the wound had been dressed by daily irrigation through drainage tubes or along the sinus tracts All sorts of fluids had been used—normal saline, plain sterilized water, iodine water, hydrogen peroxide, pure and in solutions of varying strengths, bichloride and phenol dilutions, with no appreciable improvement On September 2, I made a radical change, permanently abandoning all forms of irrigations, and substituting plain, dry, sterile dressing with immediate marked improvement in the general condition The temperature fell to 99° F and remained there, while the pulse varied between 90 and 100 There had been nervous digestive disturbances, so that any unwelcome suggestion, *e g*, the discussion of an anesthetic or the odor of ether, etc, would cause a prompt and thorough emesis Yet he had gained 10 pounds in bodily weight in five months, but with the cessation of irrigation, the digestive derangement ceased, he took and retained large amounts of food, with cod-liver oil, sevetol, etc, so that in the next five months he gained 26 pounds, with corresponding physical improvement By the middle of January, he was strong, robust, healthy appearing, but with absolutely no improvement whatever in the local lesion, which remained stationary, discharging daily large quantities of sero-pus, necessitating copious aseptic dressings

"At about this time Dr Emil Beck announced the result of his work in the treatment of certain unhealed sinuses by the *bismuth*

CHAPTER XIX

TENDON-SHEATH INFECTIONS AND MAJOR FASCIAL-SPACE ABSCESSES, PATHOGENESIS AND SOURCE OF INVOLVEMENT.

IT is urged that the reader should familiarize himself with the experimental studies and anatomy presented in the earlier chapters as a preparation for the understanding of the clinical pictures of these infections By the anatomical studies I have determined the position and relations of the tendon sheaths and the connective-tissue spaces By the experimental studies I have verified the anatomical outlines of the tendon sheaths and connective-tissue spaces and prognosticated the location of pus when extensions take place In brief the anatomical outlines and relations of the tendon sheaths and major fascial spaces are as follows

TENDON SHEATHS.—It has been demonstrated that the tendon sheaths of the index, middle, and ring fingers begin at the distal interphalangeal joint and extend one thumb's breadth into the palm The proximal end of the index tendon sheath is in juxtaposition to the lumbrical canals and the thenar space The proximal extensions of the middle and ring finger tendon sheaths are in juxtaposition to the lumbrical spaces and the middle palmar space

The tendon sheath of the little finger is generally in continuity with the ulnar bursa and the latter in a majority of cases communicates with the radial bursa The ulnar bursa extends about 1½ inches proximal to the anterior annular ligament The little finger sheath and the ulnar bursa lie in juxtaposition to the lumbrical canal, the middle palmar space, and the major forearm space

destroying the bloodvessels which run in its meshes, and so bringing about the death of overlying skin or underlying bone, not by attacking these structures themselves, but by cutting off their nourishment

"To prove this I then proceeded to inject the same doses of dead cocci deeply in the muscles themselves, beginning with 10,000,000 and steadily increasing the quantity until, on August 29, I gave him 300,000,000—and not once was there the least reaction, local or general, to a single intramuscular injection, while every one of the oblique subcutaneous injections of the same cultures, with identical septic precautions, produced local necrosis

"During this period, while we were endeavoring to do something to help the patient by means of specific vaccine, his general condition failed slightly He lost about 8 pounds in weight, and there was a slow spreading by undermining the skin around the affected area, so that at the end of this time, when this method was abandoned, the area involved reached its maximum, covering the right side of the body from the sternum into the middle of the right half of the back and extending from a point above the clavicle down beyond the costal margin—a stretch of 29 cm in each diameter I now decided to expose the affected region thoroughly, and on September 15, I curetted again all sinuses and completely excised all undermined skin At last this was followed by actual healing

"For some time I had been anxious to give my patient the benefit of sunshine in direct application to the wound surfaces, but no practicable method presented itself to me on account of the large area to be covered and the very free discharge Fortunately, on November 28, Dr Allen B Kanavel saw him and suggested a home-made wire cage This crude appliance was applied on December 3, two and a half years after the beginning of the infection, and proved to be the one missing link in the chain to drag the patient back to health The wire cage was enveloped with sterile gauze, and so enfolded and protected, my patient has spent the last ten months basking in the sunlight, with slow but steady healing of the local lesions in all spots the sun's direct rays could reach The range of pulse is in the sixties, the temperature normal and the general condition most excellent"

The history of this patient serves to emphasize that in such cases the general hygienic rules are of more value than any special procedures These include out-door life and nourishing food, combined with the least possible local treatment of the infected areas. Blood transfusions are also beneficial in these chronic cases The futility of vaccine treatment is also demonstrated by the experience in this case.

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IT is urged that the reader should familiarize himself with the experimental studies and anatomy presented in the earlier chapters as a preparation for the understanding of the clinical pictures of these infections By the anatomical studies I have determined the position and relations of the tendon sheaths and the connective-tissue spaces By the experimental studies I have verified the anatomical outlines of the tendon sheaths and connective-tissue spaces and prognosticated the location of pus when extensions take place In brief the anatomical outlines and relations of the tendon sheaths and major fascial spaces are as follows

TENDON SHEATHS.—It has been demonstrated that the tendon sheaths of the index, middle, and ring fingers begin at the distal interphalangeal joint and extend one thumb's breadth into the palm The proximal end of the index tendon sheath is in juxtaposition to the lumbrical canals and the thenar space The proximal extensions of the middle and ring finger tendon sheaths are in juxtaposition to the lumbrical spaces and the middle palmar space

The tendon sheath of the little finger is generally in continuity with the ulnar bursa and the latter in a majority of cases communicates with the radial bursa The ulnar bursa extends about 1½ inches proximal to the anterior annular ligament The little finger sheath and the ulnar bursa lie in juxtaposition to the lumbrical canal, the middle palmar space, and the major forearm space

destroying the bloodvessels which run in its meshes, and so bringing about the death of overlying skin or underlying bone, not by attacking these structures themselves, but by cutting off their nourishment

"To prove this I then proceeded to inject the same doses of dead cocci deeply in the muscles themselves, beginning with 10,000,000 and steadily increasing the quantity until, on August 29, I gave him 300,000,000—and not once was there the least reaction, local or general, to a single intramuscular injection, while every one of the oblique subcutaneous injections of the same cultures, with identical septic precautions, produced local necrosis

"During this period, while we were endeavoring to do something to help the patient by means of specific vaccine, his general condition failed slightly He lost about 8 pounds in weight, and there was a slow spreading by undermining the skin around the affected area, so that at the end of this time, when this method was abandoned, the area involved reached its maximum, covering the right side of the body from the sternum into the middle of the right half of the back and extending from a point above the clavicle down beyond the costal margin—a stretch of 29 cm in each diameter I now decided to expose the affected region thoroughly, and on September 15, I curetted again all sinuses and completely excised all undermined skin At last this was followed by actual healing

"For some time I had been anxious to give my patient the benefit of sunshine in direct application to the wound surfaces, but no practicable method presented itself to me on account of the large area to be covered and the very free discharge Fortunately, on November 28, Dr Allen B Kanavel saw him and suggested a home-made wire cage This crude appliance was applied on December 3, two and a half years after the beginning of the infection, and proved to be the one missing link in the chain to drag the patient back to health The wire cage was enveloped with sterile gauze, and so enfolded and protected, my patient has spent the last ten months basking in the sunlight, with slow but steady healing of the local lesions in all spots the sun's direct rays could reach The range of pulse is in the sixties, the temperature normal and the general condition most excellent"

The history of this patient serves to emphasize that in such cases the general hygienic rules are of more value than any special procedures These include out-door life and nourishing food, combined with the least possible local treatment of the infected areas Blood transfusions are also beneficial in these chronic cases The futility of vaccine treatment is also demonstrated by the experience in this case.

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In the forearm in addition to the superficial spaces in the loose connective tissue under the skin, we find a very important and definitely outlined space—*the major forearm space.* This lies immediately proximal to the wrist and extends half way up the forearm with prolongations along the median nerve and the ulnar artery and nerve It is bounded dorsally by the pronator quadratus, the ulna and radius and the interosseous membrane Its superficial or flexor surface is made by the tendons of the flexor digitorum profundus It is limited on its ulnar and radial sides distally by the attachment of the fascia under the skin to the respective bones Proximally it extends along the median nerve and the ulnar artery and nerve to about two-thirds of the way up the forearm from where it returns distalward between the flexor carpi ulnaris and the ulnar border of the major flexors to reach the subcutaneous tissue about the middle of the ulnar side of the forearm This is a large well-defined space having in it the proximal prolongations of the ulnar and radial bursæ.

Because of their interrelation infections of the tendon sheaths and major fascial spaces will be considered together We will first consider from what sources each of the tendon sheaths and major fascial spaces may be involved and then reverse the process and discuss the practical clinical problem into what tendon sheaths and fascial spaces will an infection spread from any given primary focus?

Concerning the surgical application of the anatomical and experimental data we have discussed in the early chapters, it should be borne in mind that our remarks are strictly confined to a discussion of these facts in relation to the subject of tendon-sheath infections and major fascial-space abscesses in the hand and forearm.

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The tendon sheaths on the dorsum are localized at the posterior annular ligament with short extensions proximally and distally

FASCIAL SPACES —In addition to the minor fascial spaces concerned in felons of the distal phalanx, frog felons, and infections about the metacarpo-phalangeal joints (bites) five major fascial spaces in the hand and one in the forearm have been determined.

The *middle palmar space* lies in the palm, bounded on the radial side by the fascia attached to the middle metacarpal bone, on the ulnar side by the hypothenar eminence, distally it extends to within a thumb's breadth of the web, and proximally to the base of the palm It lies upon the fascia covering the metacarpal bones and its superficial covering is made by the tendons with intervening fascia It is in direct communication with the lumbrical canals between the little and ring, and the ring and middle fingers

The *thenar space* lies to the radial side of the middle metacarpal bone upon the adductor pollicis (transversus) and has superficially the palmar fascia and some thenar muscles On the radial side it comes to the surface under the skin between the metacarpal of the thumb and index finger It is limited distally by the deep transverse fascia one thumb's breadth proximal to the web and proximally by the base of the palm

The *hypothenar space* is localized in the hypothenar eminence

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Lymphatic infection will be considered only in so far as it has a distinct bearing upon these conditions

ETIOLOGY IN GENERAL

In all of the cases coming under observation, the accumulations of pus have been submitted to bacteriological examination, and the results differed in no wise from the findings elsewhere, nearly all the slow-growing abscesses showing the staphylococcus in pure culture, while those originating in the tendon sheaths, if of a fulminating nature, showed the streptococcus unless there was a secondary infection The severity of the course was often in inverse relation to the extent of the primary wounds Again, the general health and resistance of the patient were often below normal The latter factor has been particularly conspicuous On the other hand, cases of localized infection (from deep lacerated wounds) have followed in very robust individuals, where doubtless the infection has been carried directly to the space infected Again, it has been noted that local trauma, without apparent abrasion of the skin, has acted by lessening the local resistance, hence favoring infection We soon learned also that the older the patient, the greater would be the danger of a serious course and complications The gonococcus may be found in some cases, almost always of hematogenous origin

SOURCE OF INVOLVEMENT OF THE VARIOUS SHEATHS

Attention has been drawn above to the theories advanced by the earlier authors as to the source of infection of the sheaths It is probable that they may be involved either by lymphatic extension or direct continuity. The latter, of course, needs no discussion That wounds involving the sheath may be an atrium and that abscesses lying in continuity may cause necrosis and involvement will be admitted by all It is rather

uncommon for a felon unaided by ill-advised incision to give rise to tenosynovitis The same may be said of suppurative arthritis of the distal interphalangeal joint, and the metacarpo-phalangeal joint This is explained by the anatomical relations, which also probably explain the frequent extension of infection from the proximal interphalangeal joint to the tendon sheath (see pp. 45 and 46) I have seen extension to a sheath from abscesses in a lumbrical canal These abscesses with such extension may be primary in the lumbrical canal or abscesses secondary to an infection in an adjoining tendon sheath. Here, however, the involvement is likely to be localized to the proximal end of the finger sheaths Indeed, this limited infection holds true for all of these cases which develop as a result of abscesses in continuity One explanation of this can be found in the fact that the contiguous inflammation has probably given rise to plastic adhesions in the sheath before the actual involvement has taken place, and, again, these local accumulations have generally been produced by the staphylococcus or some like germ of moderate virulence This is also true of involvement of the ulnar or radial sheaths secondary to the abscesses in the palm, as was exemplified by the case of Henderson (see Case XXIV)

Lymphatic involvement of a tendon sheath is not so easily demonstrable, but any surgeon can recall numerous histories of patients who have developed an infection of a sheath within twenty-four to thirty-six hours after a simple needle prick of a finger upon the volar surface This is most commonly met with in the distal or middle phalanx (see Case XIV), and is almost always streptococcic in origin Why infection of the palmar sheaths does not occur in dorsal wounds is understood when we remember that the course of the lymphatic vessels is from the palmar to the dorsal surface Frequently we see cases of tenosynovitis in which the patient cannot

give any history of injury, the abrasion or injury having been so slight as to escape notice. It is this type of infection which presages the most disastrous results, since localization to any part of the sheath is uncommon, and unless early incision is instituted, death of the synovial lining of the sheath and destruction of the blood supply of the tendon takes place with serious local and constitutional sequelæ. The possibility of gonococcus tenosynovitis of hematogenous origin must always be borne in mind in cases with an obscure origin Two such cases have come under my observation.

EXTENSION FROM ONE SHEATH TO ANOTHER

The extension from one sheath to another follows ordinarily on anatomical lines Exception to this is to be seen in a few cases, where, following a rupture of pus from a sheath into a lumbrical canal or elsewhere, an erosion of an adjoining sheath occurs with a secondary infection. The surgeon should be on his guard against this unexpected complication The gravest danger occurs when an infection of a ring finger sheath passes over into the ulnar bursa Since it is not expected the infection may become extensive without being diagnosed I have seen such an extension produce ulnar and radial bursal infection with sequential rupture into the middle palmar and thenar spaces and the major forearm space without its source and course being recognized The less complicated type is that in which the index, middle or ring fingers become involved from an adjacent tendon

As an example of such extensions I report the case of Mr. P , who had an infection of the middle finger tendon sheath which extended by way of the lumbrical canal over to the tendon sheath of the ring finger, since it demonstrates the possibility of such infection spreading to contiguous tendon sheaths, a point that has not been brought out in previous contributions

CASE XIV —Mr P , referred by Dr A T Horn

History Patient received slightly lacerated wound on the flexor surface of the middle finger. Inside of two days the finger was markedly swollen and tender, and when seen in consultation on the third day tenderness was marked throughout the course of the tendon sheath, the finger was flexed and on extension presented the greatest amount of pain at the proximal end of the sheath

A diagnosis of tenosynovitis was made and the tendon incised throughout its length The lumbrical spaces on either side were involved and were drained The infection apparently subsided, but on the seventh day it was noted that the ring finger was markedly flexed, tender throughout the course of the sheath, and that on extension pain was present at its proximal end The diagnosis of infection of this sheath due to contiguity of the lumbrical space was made, and the tendon sheath was incised and drained by an incision upon its flexor surface From this time on there was an uninterrupted recovery as to the infection, but the ultimate result showed the patient with moderate flexion of the ring finger at its proximal interphalangeal joint, no motion at its distal joint, and complete motion at the metacarpo-phalangeal joint The middle finger was held semiflexed with complete flexion at the metacarpo-phalangeal joint, other joints of the finger could not be moved

The surgeon should also remember that exceptionally there is an anatomical union of one or more of the radial finger sheaths with the ulnar bursa Here also infection would spread by continuity into the ulnar bursa Apparent exception to the rule of spread of pus by continuity of the sheaths is found in the simultaneous involvement of the thumb and ulnar bursa without involvement of the radial bursa, the thumb being primary, as was found in four of Forssell's cases It is my belief that such observations are generally an error and that this exception is very rare He did not note any cases of little finger infection and radial bursitis without associated ulnar bursitis In two of my cases I was led to the same conclusion on first opening the sheath of the flexor pollicis longus, but further search revealed pus at both ends of the sheath

The anatomical relations of the tendon sheaths of the little finger and thumb to the ulnar and radial bursæ respectively, as well as the intercommunication of these

latter, have already been discussed (see pp 46 and 51). When we are dealing with an infection of little virulence, such as one due to the staphylococcus, we frequently find a plastic exudate or adhesions closing the narrowed opening between these parts and the infection located in any section, as, for instance, the digit sheath, ulnar bursa, radial bursa, or the intermediary sheaths at the wrist Indeed, I have at times seen an infection of an ulnar bursa limited to that part of the sheath between the base of the finger and the transverse carpal ligament, the part of the sheath in the forearm being uninvolved, protected by adhesions at the annular ligament

In general, however, it may be said that in the virulent types of infection beginning in the little finger sheath, we will almost always have an involvement of the ulnar bursa and in a majority of cases of the radial bursa The sheath of the flexor pollicis longus will also be involved if operation is delayed The converse is also true I do wish to emphasize, however, that if operated upon early an infection extending from the radial bursa to the ulnar bursa will be found very commonly at that time not to have spread to the tendon sheath of the little finger

The extension from the sheaths by rupture has been discussed in the chapter on Experimental Injections, and will be considered in the subsequent section upon the source of involvement of the fascial spaces

Exceptionally the sheaths may become involved as a sequence of a systemic infection Cases have come under my observation following both gonorrhea and puerperal infection.

SOURCE OF INVOLVEMENT OF THE IMPORTANT FASCIAL SPACES IN THE HAND GENERAL DISCUSSION

The major fascial spaces may be infected by extension from the tendon sheaths, by direct implantation, through the lymphatics, or by extension from other fascial spaces

INVOLVEMENT FROM THE TENDON SHEATHS —This source is one of the most common, and the experimental and anatomical discussions in the early chapters had for one of their purposes the determination of how this occurs Accepting the results of these investigations as probabilities only, I have been able to verify nearly every statement by clinical observation In the less virulent cases inflammatory barriers may be thrown out that will close the normal anatomical canals If the process continues any time, however, or the process is acute, the result follows absolutely along anatomical lines

DIRECT IMPLANTATION OF THE INFECTION IN THE SPACES —The *middle palmar space* is infected by implantation, both through direct puncture and extensive crushing injuries and lacerated wounds

CASE XV —Crushing injury of hand, fracture of middle finger metacarpal, with infection involving the middle palmar space

Mr B P, aged twenty-five years, Chicago Charity Hospital

Patient's Statement Patient states that he was thrown in front of a moving car and the wheel ran on his hand, but evidently did not cross it Condition found upon entrance to hospital on following day Lacerated wounds across dorsum of right hand, midway, 2½ inches long, rather deep, into subcutaneous tissue, lacerated wound of palmar surface, 2 inches long and irregular, so that there was a flap raised up consisting of tissue superficial to palmar aponeurosis, wounds infected, fracture of metacarpal of middle finger, tendons intact, fingers extended, not particularly tender to flexion and extension, although thumb was more tender than others (This was later found to be due to a fracture of the proximal phalanx) Whole hand swollen, no particular areas Flaps opened to allow drainage Hot boric dressings applied

Patient's temperature and pulse demonstrated a continuation of the severe infection, and two weeks after entrance, owing to the site of the injury and the greater rigidity of the middle, ring and little fingers, a diagnosis of pus in the middle palmar space was made Proximal phalanx extended, two distal phalanges flexed 45 degrees from the same line Incision into middle palmar space disclosed abscess there in communication with the fractured metacarpal Through-and-through drainage from palm to dorsum instituted Rapid fall of temperature and pulse followed Drainage was free

Edema and swelling continued for some time, beginning to decrease, however, at the end of the first week.

January 29 (second day) Temperature, 101 5° to 102⅙° F, pulse, 70 to 104

January 30 Temperature, 101° to 103 25° F, pulse, 80 to 108

February 1 Temperature, 101 5° to 101 25° F, pulse, 100 to 108

February 3 Temperature, 99° to 99⅛° F, pulse, 92 to 104

February 4 Temperature, 98⅙° to 99 5° F, pulse, 80 to 92

February 6 Temperature, 99 5° to 102 5° F, pulse, 88 to 92

Here the infection evidently extended.

February 9 Temperature, 100 5° to 101⅙° F, pulse, 84 to 90

February 11 Temperature, 99 25° to 104⅛° F, pulse, 84 to 92

February 13 Temperature, 100° to 103 25° F, pulse, 96 to 124

February 15 Temperature, 100 25° to 101⅙° F, pulse, 76 to 90

Operation Middle palmar space drained.

February 17 Temperature, 99 25° to 100 5° F, pulse, 96 to 100

Temperature curve begins to fall and septic symptoms decrease Sleeps well and begins to eat

February 19 Temperature, 99 5° to 101 25° F, pulse, 92 to 96

February 22 Temperature, 99⅙° to 101° F, pulse, 94 to 96

Drain removed

Gradual fall until March 3, when the temperature fell to normal and remained there

March 20 Temperature and pulse normal, hand still swollen and little movement in fingers, position of digits same as upon entrance, can move all slightly without pain, index most of all, thumb slightly tender to passive movements (fractured) Other fingers little pain produced by manipulation

April 20 Hand improved much, much greater range of movement of fingers, evident that nearly full functions will be restored

In deciding, however, whether or not the middle palmar space has been invaded by injury, it is well to bear in mind that the space lies dorsal to the tendons and superficial vessels, hence these can be uncovered by a lacerated wound, and the space not necessarily become involved, although it is probably true that unless scrupulous care be taken to give perfect drainage superficially, the space will later become involved, since the fascial sheet separating the tendons and the loose connective tissue about them from the space is very thin, as has already been pointed out. This same fact is to be remembered in case of a punctured wound since, while the loose cellular

tissue surrounding the tendons, superficial vessels, and the lumbrical muscles would harbor pus for a short time, if not properly drained it will extend to the space If intervention is withheld for any length of time it must extend either down along the lumbrical muscles, through the fibrous canal at the distal part of the palm already noted, and thence into the cellular tissue dorsal to the web, or break into the palmar space, and in nearly every case the latter result will be found to have occurred long before the former Since the interstices of this loose connective tissue seldom alone harbor pus for any length of time, it has not seemed to me wise to dignify this area by designating it as one of the major spaces of the palm.

Owing to the juxtaposition of the metacarpal bones, particularly of the middle and ring fingers, any crushing injury of the hand, with consequent compound fracture of these bones, will frequently lead to infection through this dorsal wound, as I myself have seen (Case XV) The metacarpal bone of the little finger, being separated from the middle palmar space, is not so likely to be the source of involvement of that space, but may lead to infection of the hypothenar space Injury to the metacarpal bone of the index finger (and in exceptional conditions the middle finger) will open the thenar space. Compound fracture of the thumb metacarpal would more likely lead to dorsal subcutaneous accumulations of pus, or even synovial infection of the sheath of the flexor pollicis longus, than thenar space infection It is well to bear these predisposing etiological factors in mind when we come to discuss the diagnosis of the position of the pus

The relation of the other major spaces to direct implantation needs no special consideration.

Involvement by Lymphatic Extension —There is abundant clinical proof that infection can spread by lymphatic channels, and abscesses develop at distant

spots Upon the other hand, it is often impossible to say whether an extension has occurred by means of the lymphatic vessels, or by means of the spaces, and fortunately in these cases it is not necessary to decide the question, since the two courses are generally side by side Thus, the deep lymphatics pass from the fingers along with the vessels in the same space in which the lumbrical muscle lies, and in a given case, for instance, an infection at the base of the ring finger which spreads into the middle palmar space, who can say whether it extends by means of the lymph vessel or along the lumbrical muscle, going to the radial side of that finger? Moreover, we do not need to know What is of importance is to know where the pus lies after it has extended, and certainly a study of the course of the lymphatic channels is of importance in relation to this It is not our purpose to discuss the subject of lymphatic infection as a whole, nor do more than draw attention to the monumental works of Sappey, Leaf, Malgaigne, and others, by which we can, in some measure, prognosticate the position of a metastatic abscess when the point of primary infection is known

The superficial lymphatics upon the palmar surface pursue the shortest course to the dorsum Thus, for instance, an infection starting upon the distal part of the palm would go between the web of the fingers to the subcutaneous tissue of the dorsum Hence, should an abscess develop as a result of this, it would be found in the dorsal subcutaneous area Should a lymphangitis be present, however, without localized abscess formation, the swelling in this region would be just as great, owing to the edema which develops in the loose tissue found here This will be brought out later in discussing the diagnosis. Should the deep lymphatics be involved, the infection will follow the deeper vessels, hence passing into the palm Theoretically speaking, then, an infection spreading from the adjacent sides of the little and ring

fingers, and the ring and middle fingers, would lead to an accumulation of pus in the middle palmar space, while an infection of the radial side of the index finger would extend to the thenar space and one of the adjacent sides of the middle and index fingers, while probably extending to the middle palmar space might extend to the thenar space. Other infections upon these fingers more dorsal would follow the deep vessels under the aponeurosis upon the back of the hand, thus producing a subaponeurotic abscess

Unfortunately, sufficient clinical evidence has not accumulated to prove these assumptions, although Chevalet and Dolbeau, particularly, have presented cases showing this complication, especially those showing extension and development of an abscess under the dorsal aponeurosis. The proof of an extension to the palmar and thenar spaces is much harder to demonstrate, for the reasons that have already been pointed out After an experience of over twenty years in which I have observed some hundreds of infected hands, I myself, however, am unable to present a single case in which I could prove such an extension and it is my personal opinion that secondary abscess in the palmar space is seldom if ever due to lymphatic extension alone

Dolbeau has drawn attention to the frequency of infection along the course of the radial artery in the forearm, due in his judgment to extension from the thenar region along the radial lymphatics He also notes the presence of abscesses along the ulnar artery and in the deep tissues in the forearm, originating, he believes, by a lymphatic extension around the anterior interosseous That these occur is possible, but in this connection the reader will remember the experimental injections of the palmar space, and the ulnar and radial bursæ where the mass spread by continuity of tissue, under the tendons into the forearm, and then involved, secondarily, both the radial and ulnar areas mentioned (Experiments 46 to

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annular ligament behind the tendons, immediately over the wrist-joint, thence into the forearm, lying upon the radius, ulna, interosseous membrane, and its attached muscles, and the pronator quadratus, covered by the flexor digitorum profundus, thus filling the entire space from the elbow to the wrist before it comes to the surface laterally 2 or 3 inches above the wrist-joint (Experiment 49). This extension would take place in at least two-thirds of the injections of the palmar space if force were used. But now enters the question of destruction of tissue at the wrist-joint, swelling of the tissues under the transverse carpal ligament, and the plastic exudate, which would tend to close this natural exit That this occurs in a majority of the cases we have abundant clinical evidence I have not had a single case in which pus extended from the middle palmar space to the forearm, but in corroboration of the experimental data we find the report of a postmortem done by Professor Dolbeau, and reported by Chevalet in his Paris thesis of 1875 The extension under the synovial sheath, without invading it, and the involvement of the forearm, with diverticulum along the radial, all make a picture the duplicate of Experiment 49 It will be noted that the pus occupies the exact outlines of the middle palmar space, bathes the free portions of the tendons in juxtaposition to the palmar aponeurosis, and yet it is specifically stated that the abscess cavity lay dorsal to the tendons An abstract of the case report follows

Case XVI —"At the hand the lesion is limited to the middle palmar region, the two eminences, thenar and hypothenar, are intact In the middle palmar region the aponeurosis is raised with some difficulty, the tissues, infiltrated with plastic matter, form a thick layer as if lardaceous, in the deep part of which are plunged the superficial palmar arch and the terminal ramifications of the median nerve

"These organs being dissected and raised, one begins to uncover the tendons in their palmar portion, and in order to be able to

49), and this I believe is the usual source of such abscesses A frequent secondary localization by lymphatic extension from ulnar and radial bursitis is that found in the subcutaneous tissue on the flexor surface proximal to the wrist

The reader is referred to the chapters dealing with the anatomy and surgery of lymphatic infections for other detail concerning this subject

EXTENSION FROM ONE FASCIAL SPACE TO ANOTHER —In the preceding section we have answered the question as to the source of involvement of the various spaces We now arrive at the next question which confronts the surgeon. With a given space already involved, to what other spaces could the infection extend, and by what course? The question now becomes one more of pathology than anatomy, and while the infection still retains its full relation to the anatomical peculiarities of a part, yet the destruction of tissue incident to long inflammation must be taken into consideration. The longer one studies the question the more prone he is to ask whether many of the complicating extensions are not due either to inadequate treatment, or an improper idea as to the position of the pus, and consequently the institution of incisions which tend to favor the extension of the infection as much as to give proper drainage

Let us take the *palmar space* Here the question of extension has been studied by injection. The pus would have a natural tendency to spread in two ways: First, along the lumbrical muscles of the little, ring, and middle fingers, and thus point, in time, in the connective tissue of the web upon the dorsum This we know has occurred in long-standing cases, in spite of the pseudoclosure of the canal at the lower end and its narrowness, which would thus favor closure by inflammatory exudate (see roentgen-ray plate, Fig. 26, and schematic drawings, Figs 24 and 25). Secondly, the pus may exceptionally pass under the

can be affirmed is that the lesion so limited by the sheath has not been there for nothing, since this sheath is intact at the level of the articulation

"In dissecting the forearm, one is struck, first of all by the apparent integrity of its anterior region The lesions are, in fact, very deep Alone, the sheath of the radial vessels appears diseased from the first inspection It is, in the interior half of the forearm region, infiltrated with a plastic matter which gives to it the appearance of a whitened cord with granulated surface The artery plunged in the middle of this plastic matter is detached from it only with difficulty, and by dissecting it with care The sheath of the ulnar is intact, the median nerve presents nothing at all particular, the muscles are intact also, at least those of the superficial layers, because in dissecting the deep flexor one finds beneath it, or rather in its thickness, in front of and inside of the ulnar bone, a purulent foyer of about the volume of a small egg This foyer, situated at the middle part of the forearm, well limited below, at least upon the anterior region of the forearm, is without communication with the lesion of the palm of the hand, and, with that which we shall see presently, exists at the level of the pronator quadratus In seeking what has been its point of departure, one finds it at the side of the ulnar bone This latter has been the seat, in its inferior half of the suppurative periostitis, and is almost totally denuded, even to the middle of its length The foyer that we have just indicated is a tributory of the subperiosteal foyer, which bathes the bone from the back and the inside The origin of this periostitis appears to have been the rupture of the articulation full of pus, which was opened from the back

"In raising, at the wrist, all the tendons, the flexors, one begins to uncover a second foyer situated between these tendons and the pronator quadratus This muscle altered but not destroyed, separates this foyer from the ulnar bone, so that there exists no relation between it and the osseous lesion On the contrary, this foyer communicates by the proper canal, behind the sheaths of the tendon, with the palmar foyer"

We now ask ourselves What are the probabilities for extension when these normal exits are closed? In what way will the inflammatory destruction of barriers show itself? The pus cannot break through the firm palmar aponeurosis We first turn our attention to the adjacent thenar space We remember that the lower, or distal portion of the intervening wall is very firm, but that at the proximal end, the dividing tissue is rather thin,

examine them in their whole length, the annular ligament of the carpus is incised

"The sheath of the tendon of the long flexor of the thumb is intact in all its length, at the thumb, at the palm of the hand, under the annular ligaments, and above this ligament the cul-de-sac by which it terminates Let us recall that it is upon the thumb that the initial wound is found the point of departure of all the trouble But the sheath of the flexor longus pollicis is absolutely intact

"In examining the ulnar sheath one finds the following The portion of this sheath destined to cover the tendons of the superficial flexor is little altered, and these tendons, save that of the little finger, are relatively intact The portion of the sheath destined to cover the tendons of the deep flexor is much more diseased, especially at the level of the tendon of the little finger In examining the sheath of this tendon one finds it intact in its digital portion The tendon presents there its mother-of-pearl appearance, and is absolutely sound But if one follows it to the palm of the hand, one sees it penetrate into a purulent foyer, which occupies the deep part of the hand The tissue about bathed in pus is diseased Likewise the tendons which it envelops for a stretch of about 4 cm of the tendon of the little finger, of 2 5 cm to 3 cm of the other tendons, index, middle and ring Above this point the sheath and the tendons take again their character of integrity and keep it in the carpal canal, even to the terminal cul-de-sac of the sheath

"In raising the tendons of the deep flexor, one begins to uncover a purulent foyer occupying the deep palmar region, situated exactly upon a median line (*par rapport*) in relation to the axis of the hand, and corresponding exactly to the deep palmar arch that one sees placed against its posterior wall Its anterior wall is formed by the sheath of the deep flexor tendons that it flooded over It is prolonged along the sheath of the tendon of the little finger At one point the sheath is open and the pus traverses it in such a manner as to come to show itself beneath the palmar aponeurosis, but, a thing to notice, it does not spread into this sheath, neither at the lower part, toward the little finger, nor in the upper part in the carpal canal

"The radio-carpal articulation is filled with pus, its cartilages are destroyed, the osseous surfaces which supported them are eroded The triangular ligament partly destroyed allows the radio-carpal articulation to communicate freely with the inferior radio-cubital articulation

"The articulation of the first row of the carpal with the second is in the same condition, likewise the articulation of the bones of each row between them, especially of the first What is the origin, what has been the mode of production of this suppurative arthritis of the wrist? It is a question not easy to decide, but that which

space we have described as lying under the flexor profundus

Suppose the *thenar space* is primarily involved, the pus here does not so readily extend into the forearm (See Experiments, Forcible, Nos 29 to 33) Here probably the weakest place lies toward the dorsum, either



FIG 114 —Scars showing where subaponeurotic abscess has pointed Note four openings at the edge of the aponeurotic sheet Note prominence of tendons, *i e*, suppuration beneath

above or below the adductor pollicis (transversus), thus the dorsal subcutaneous space becomes involved between the thumb and index metacarpal, and between the adductor pollicis (transversus) and first dorsal interosseus, where there is a large, cone-shaped cavity. (See Experiments Nos 29 to 32) It should be borne in mind, however, that this result is not obtained easily, since the pus

and it is very easy to suppose that the infection may destroy this and thus invade the radial side Experimentally, this can be seen to occur (See Experiment 20, Fig 24) This, however, would not occur until late, since most of the pus is at the distal part of the hand. But that it does occur frequently in neglected cases I have abundant clinical evidence It is one of the most common of the extensions.

Again, the pus might extend along proximally the lumbrical muscle of the middle finger, and rupture from here into the thenar area

Upon the hypothenar side there is so much tissue intervening between the middle palmar space and the hypothenar that we would not expect this to become involved and personally I have never seen such an extension

Text-books all tell us that the pus in these cases finds exits between the metacarpal bones, and thus escapes to the dorsum When one studies the dense layer of fascia spreading from bone to bone, upon both the volar and dorsal surfaces, being really an anterior and posterior interosseous membrane, with the interosseus muscles between, and a division between them being often difficult to find, we are led to wonder if this complication really occurs as early in the course of the disease as we are led to believe Probably the edema upon the dorsum has been mistaken for pus, and the spurious corroboration obtained by through-and-through drainage. By no means can it be denied that at times later in the course following an osteomyelitis of a metacarpal the pus may find this means of exit When it does, it first comes to lie in the subaponeurotic, and then in the subcutaneous tissue. I personally have never seen such a case unless there was an osteomyelitis of the metacarpals or carpal bones

Another course of extension is sometimes seen in which the ulnar bursal sheath is involved by contiguity, spreads along the tendons, and ruptures into the forearm in the

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of the thenar space may exceptionally rupture into the middle palmar space It may be infected by direct implantation or osteomyelitis of adjacent metacarpals and possibly by lymphatic extension from adjacent areas

The *thenar space* may be involved from rupture of pus from the proximal end of the tendon sheath of the index finger Exceptionally it may be involved from rupture of the tendon sheath of the middle finger or the sheath of the flexor longus pollicis and the radial bursa. Infection in the lumbrical canal between the index and middle fingers may spread to this space In neglected cases pus will rupture from the middle palmar space into the thenar space It may also be infected by direct implantation or osteomyelitis of the index metacarpal and exceptionally from that of the middle metacarpal

The *lumbrical spaces* are most commonly the site of the primary focus after rupture from the proximal end of the various sheaths The middle and ring finger sheaths may rupture on either or both sides The index finger most commonly ruptures to the ulnar side, but may rupture upon the radial side while the little finger sheath ruptures only upon its radial side These spaces are also frequently involved in frog felons Pus in the middle palmar space may extend into the three ulnar lumbrical spaces, that from the thenar spaces extends into the space radial to the index finger

Since few lymphatics lead into the *hypothenar space*, and it is isolated from adjacent areas by densely circumscribed tissue, infection here is due most often to direct implantation For instance, a palmar infection will extend through the lumbrical canals to the web between the fingers or will rupture into the ulnar bursa before it will overcome the resistant tissue intervening between it and the hypothenar space (see cross-sections, Figs 7 and 8) The space can be infected, however, from the dorsum, through a compound fracture of the fifth meta-

will often remain for days confined to the thenar space (Case XVII). In long-continued or anomalous cases it can spread proximally along the lumbrical muscle of the index finger, infect the loose connective tissue about the palmar tendons, and thus infect the palmar space, or can rupture into the palmar space through the upper end of the septum separating these two spaces. (See Experiments 29 to 35.) This complication should be rare, however, in properly treated cases.

In case the *subaponeurotic space* is infected by osteomyelitis, or otherwise, there might be considerable variation in the course the pus would pursue, if the sheet is dense, as it is in a majority of cases. The suppurative process wound tend to extend under the aponeurosis and point laterally, upon either side, at the thinner tissue there, thus becoming subcutaneous, or at the distal margin between the metacarpo-phalangeal joints, as I myself have seen. However, in some patients the aponeurosis will be found to have thin areas between the tendons, and then the purulent matter would become subcutaneous through these small openings. In all probability, however, before any of these things happen, operative interference will have opened the abscess (Fig. 114).

SUMMARY AS TO THE SOURCE OF INVOLVEMENT OF THE MAJOR FASCIAL SPACES.—The *middle palmar space* may be involved secondarily to a tendon-sheath infection of the middle, ring, and little fingers or from the ulnar bursa. At times when the middle finger tendon sheath ruptures into the lumbrical space between the middle and index fingers the infection may involve the thenar space but in a majority of cases it will extend to the middle palmar space. It may be involved by extension from frog felons or other infections lying in the lumbrical canals between the little and ring, and ring and middle fingers and at times from an infection originating in the canal between the index and middle fingers Abscesses

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carpal, but even then the pus would be more likely to accumulate upon the dorsum, owing to the intimate relations of the hypothenar muscles to the bone, than to involve the hypothenar space, unless the injury of the muscles is extensive

Direct infection of the *subaponeurotic space* can occur by punctured or incised wounds, or by crushing injuries compounded particularly upon the dorsum The incised wounds, lying transverse to the tendons, would be less likely to lead to subaponeurotic accumulations of pus, owing to the retraction of the aponeurosis by the extensor muscles, thus opening the gap widely so that free drainage would ensue into the subcutaneous tissue or externally Longitudinal cuts, on the contrary, would tend to close, and thus prevent free drainage

The *subcutaneous tissue* is infected in the same manner It also can be invaded in the pileous infections occurring upon the dorsum, which at times become carbuncular in their nature, thus extending from the skin proper into the subcutaneous tissue

The *major forearm space* is involved by rupture of pus from the proximal end of the ulnar and radial bursæ Very exceptionally pus may extend into this space from the middle palmar space I have never seen this extension It may be involved by direct implantation or osteomyelitis of the distal ends of the ulna or radius Theoretically abscesses may develop along the radial or ulnar artery and involve this space although it has happened only once in my experience

CHAPTER XX

THE SPREAD OF INFECTION FROM ANY GIVEN PRIMARY FOCUS

THIS will be discussed under three heads—the possible spread from primary foci on the digits, from foci on the palm, from foci on the dorsum. Infection may spread by three channels: (*a*) lymphatic, (*b*) fascial, (*c*) along the synovial sheaths Extension by the lymphatic vessels is excluded from this discussion since it has been discussed in the previous chapter In this chapter we will consider only extension by the fascial spaces and tendon sheaths

THE PROBABLE EXTENSIONS FROM PRIMARY FOCI ON THE DIGITS

THE SPREAD OF INFECTION INVOLVING THE THUMB.

Infection of the thumb would at first glance seem to offer the most favorable course for pus to extend into the thenar space But let us consider for a moment Lymphatic extension does offer some chance, if the infection be deep and upon the ulnar side. Upon the other parts, however, the tendency would be for the pus to be carried away from the space

The synovial sheath of the flexor pollicis longus lies some distance from the space, and hence pus would tend to come to the surface if the sheath ruptured in its course. It can be seen, however, that if the sheath ruptured in its distal part, and the infection thus became an infection of the connective-tissue spaces, it could spread along the ulnar side of the thumb, and by considerable destruction

of connective tissue come to lie upon the origin of the adductor pollicis (transversus) and thus invade the space In the majority of cases, however, the pus would rupture from the sheath into the major forearm space (For further discussion of tendon-sheath extensions, see Chapters IV and XXII)

Should the infection be located in the subcutaneous tissue the pus would extend more easily to the surface Deep infections lying under the web between the thumb and index finger may involve the thenar space

The Spread of Infection Involving the Index Finger

Fascial-space Extension —The extension by the fascial spaces is easy to follow when we study the series of cross-sections (Figs 115 to 122) By studying these we see there is loose connective tissue surrounding the phalanges in which infection could spread with ease Upon the dorsum it might go up into the subcutaneous tissue in the back of the hand, internally, it would come to lie in the cellular spaces at the web between the index and middle fingers, and could even spread along the lumbrical muscle of the middle finger into the palm, and thus invade the middle palmar space This latter extension, however, would be more likely to occur in a deep inflammation involving the proximal phalanx of the middle finger, if at all, since, as a general rule, the pus would come to the surface before extending along the lumbrical canal

Upon the radial side of the index finger there would be still less likelihood of the pus entering the lumbrical canal in preference to coming to the surface, since this canal is not so well marked Of course, it could not extend upon volar side into the palm, because there is no connecting space (see Figs 116 and 120) Again, we note that if the pus were under the dorsal aponeurosis of the proximal phalanx, it would be limited to this area, since it is a

closed space and does not communicate with the subaponeurotic space upon the dorsum of the hand. Thus, we see that while it is possible for the thenar space to

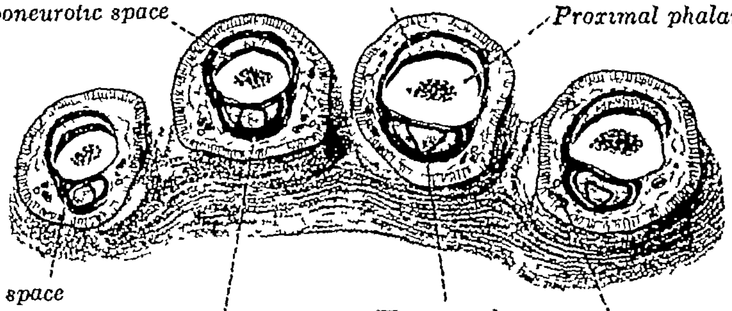


FIG 115 —Cross-section No I The tendon sheaths are shown in red

become infected by fascial-space extension from the index finger, it is not probable Extension from a metacarpophalangeal infection has been discussed in Chapter XIII.

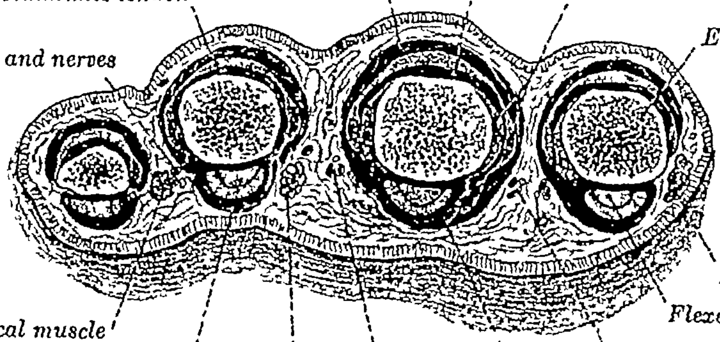


FIG 116 —Cross-section No II Through epiphysis of proximal phalanx The tendon sheaths are shown in red

The question now arises, however, should the pus lie either primarily or secondarily in the subcutaneous tissue upon the dorsum of the hand in the region of the index metacarpal, could it spread around the radial border of

the index metacarpal into the thenar space? Again, should it lie in the subcutaneous tissue between the index

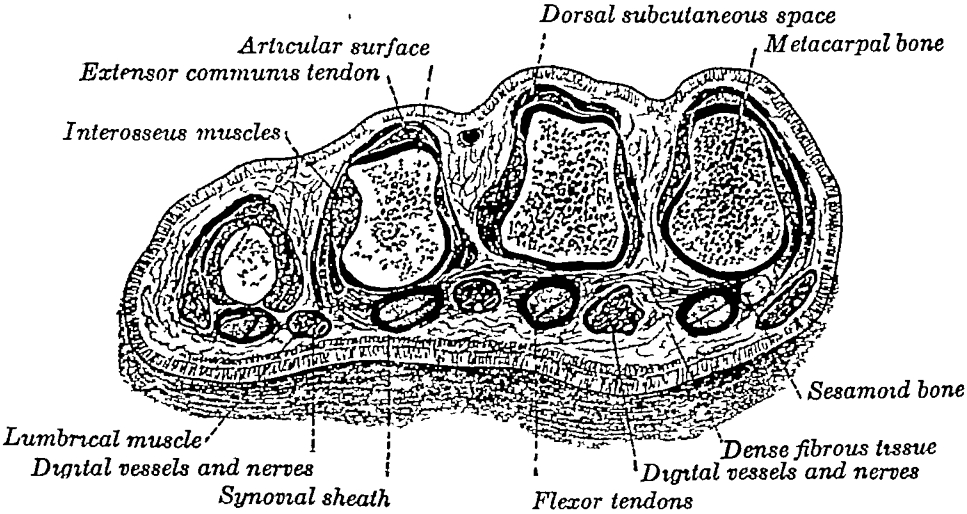


FIG 117 —Cross-section No III Proximal to metacarpo-phalangeal joint The tendon sheaths are shown in red

and thumb metacarpals, could it pass under the web into that space? The study of the cross-sections (Figs 119

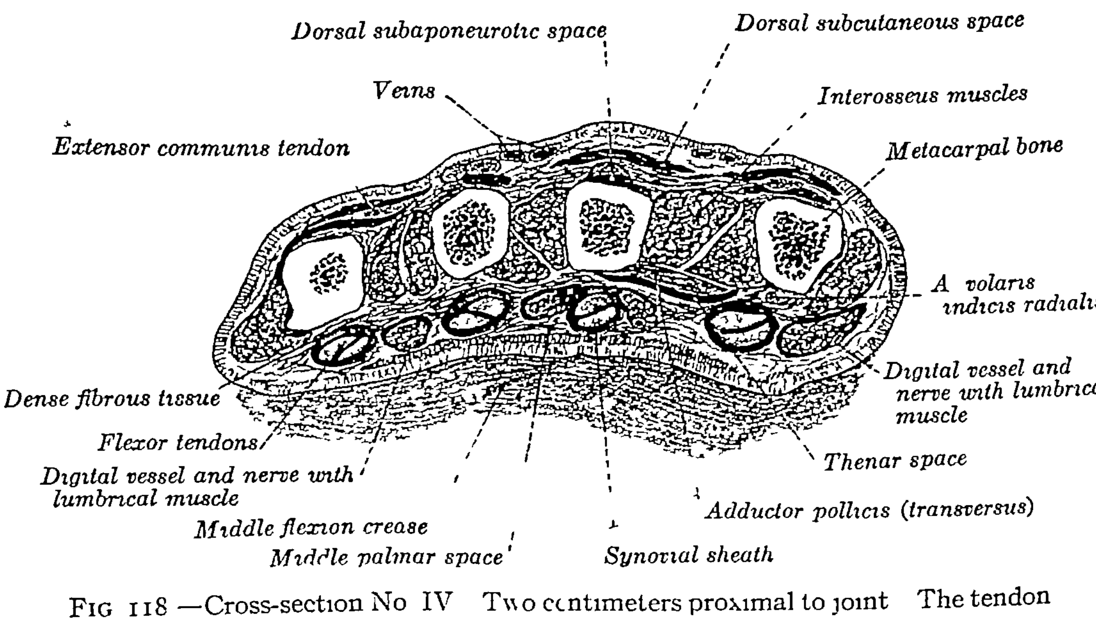


FIG 118 —Cross-section No IV Two centimeters proximal to joint The tendon sheaths are shown in red Note the beginning of the middle palmar space

and 120) as well as the experimental injections (Nos 39 and 40) seem to show that this is not probable Clinical

evidence can be adduced to corroborate this The pus would rather come to the surface upon the dorsum The subaponeurotic accumulations, unless complicated by an osteomyelitis would also follow the same course. (See Experiments 25, 26*A* and 27, Figs 119 to 120)

SYNOVIAL-SHEATH EXTENSION.—We now come to the third method of extension—by the index synovial sheath Let us suppose that the synovial sheath has become filled

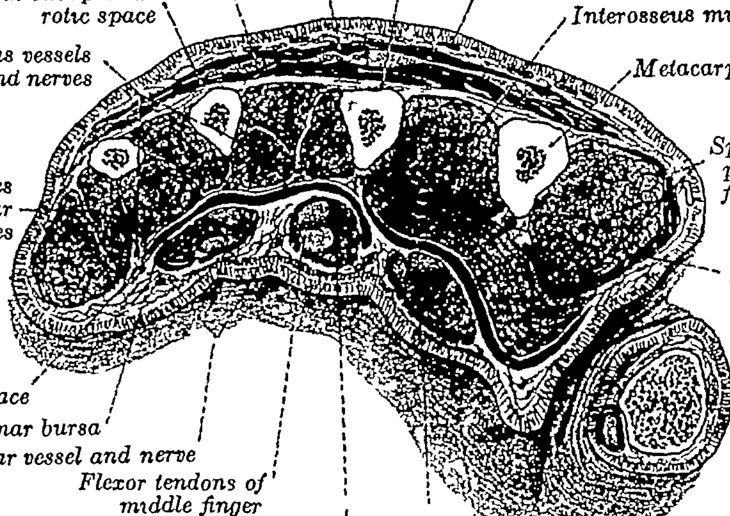


FIG 119 —Cross-section No V Three and a half centimeters proximal to joint The tendon sheaths are shown in red (ulnar bursa and radial bursa)

with pus and an extension taken place into the hand along this sheath Here the anatomical, experimental, and clinical evidence is clear (See cross-sections, Figs. 118 and 119, Experiments 8, 9, 27, and 35, Case XVII) Having ruptured from the proximal end of the sheath, which is very thin generally, the pus would lie in the loose connective tissue which surrounds this tendon and the lumbrical muscle After a short time, as the infection persisted, or the accumulation of pus grew, it would

follow the lines of least resistance, and run along the lumbrical muscle toward the radial side of the index finger

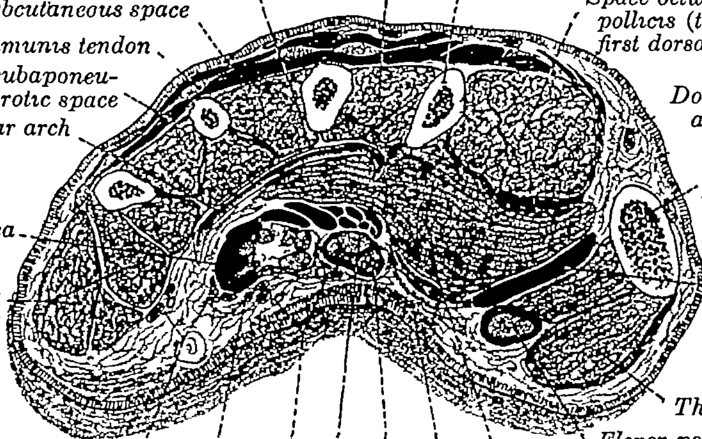


FIG 120 —Cross-section No VI Through distal part of thenar area The ulnar and radial bursæ are shown in red

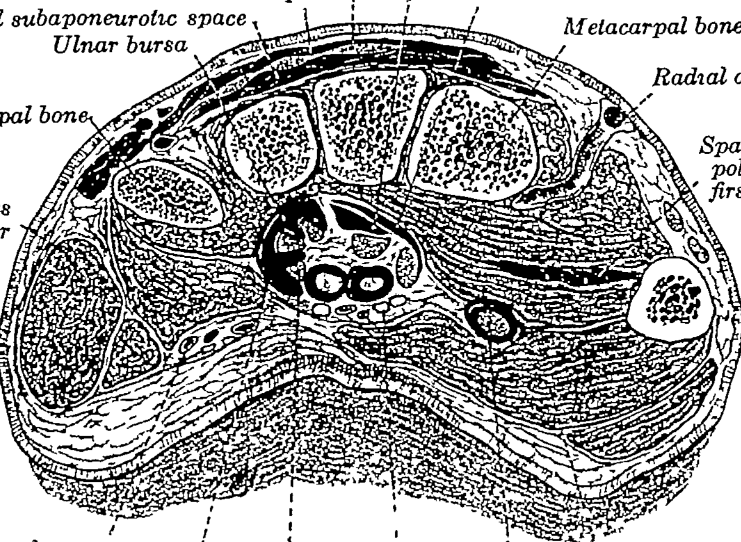


FIG 121 —Cross-section No VII The ulnar and radial bursæ and the intermediate tendon sheaths are outlined in red

(Experiment 8, Fig 123), and, being limited here, would then rupture through the thin sheet of fascia, separating this tissue from the thenar space (cross-sections, Figs 119 and 120), and thus become a thenar space infection At times it may involve the lumbrical canal between the index and middle metacarpals. If it spreads upward from here it will generally involve the thenar space but

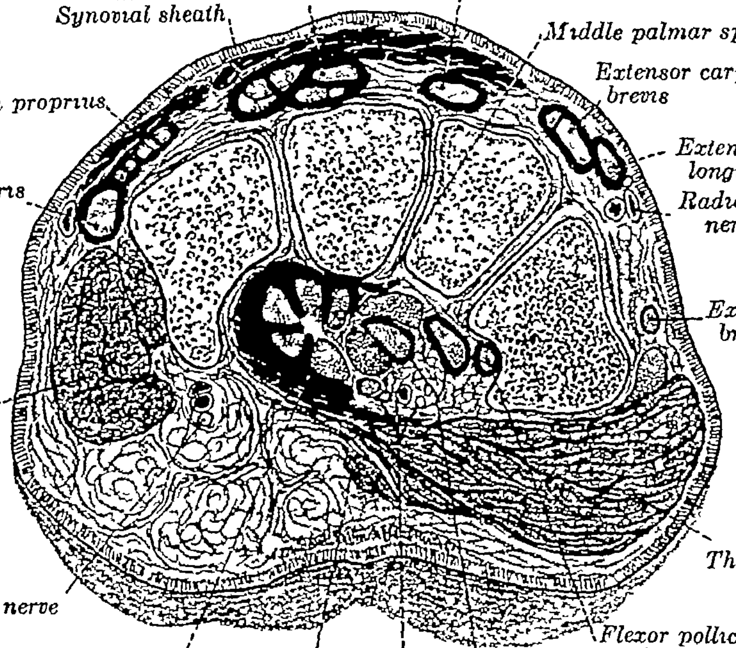


FIG 122 —Cross-section No VIII The ulnar bursa, radial bursa and intermediate sheaths are shown in red

may involve the middle palmar space (For tendon-sheath extensions see also Chapters IV and XXII.)

Arthritis of the proximal interphalangeal joint not uncommonly follows neglected tendon-sheath infection.

Exceptionally the tendon sheath of the middle finger may become infected by erosion following rupture of pus from the index sheath into the intervening lumbrical space

The following case corroborates these deductions·

CASE XVII —Seen in the service of Prof F A Besley at the Post-Graduate Hospital

Diagnosis —Infected wound of index finger, tenosynovitis of index tendon infection of thenar space, ultimate amputation of finger

September 2 T W Ten days before coming to the hospital the patient cut his finger just above the metacarpo-phalangeal joint on a tin can, wound slightly to radial side of dorsum This became infected, and the patient consulted a physician, who opened the wound and passed a drainage tube through and across the dorsum,

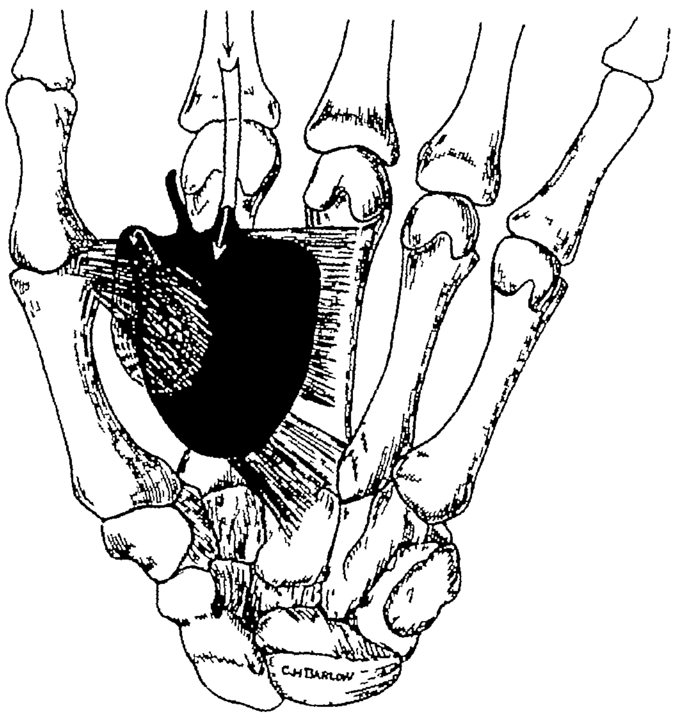


FIG 123 —Schematic drawing made from a dissection of a hand injected along the tendon sheath of the index finger Mass filled thenar space and extended around to the dorsum underneath adductor transversus and also along lumbrical muscle

coming out between the index and middle fingers Upon examination the finger was seen to be much swollen, as was the entire hand, particularly the dorsum Several openings appeared about the proximal phalanx A probe into one of these found rough bone and easily entered the metacarpo-phalangeal joint The entire finger and hand were slightly tender, but marked and conspicuous tenderness was elicited over the site of the tendon sheath, and sharply limited by it, being most acute at the proximal end over the metacarpo-phalangeal articulation Flexion of finger did not increase pain, extension of

index finger caused marked pain through finger, but most sharply noted by patient at proximal end of sheath Extension of other fingers caused little increase of pain, no particular pain on dorsum of finger where cuts were found Temperature, 101° F, pulse, 92 Infection of foot present also, as well as small boil on opposite shoulder Epitrochlear and axillary glands swollen out of proportion to those in left arm (Patient's resistance is evidently far below par) Systemic symptoms marked Neutrophilia, 94 per cent

Clinical Diagnosis Infected wound of hand, probably staphylococcus, infected index tendon sheath, extension to glands of axilla and elbow and, in addition, infection of skin on shoulder and in foot Etiology of latter unknown—possibly pyemic from hand, infected knuckle-joint

Prognosis Will probably lose finger

Operation Tendon sheath opened from end to end Pus in moderate amount evacuated Dorsal openings previously present enlarged Hot boric dressings Foot opened and drained Temperature ran 99° to 101° F every day

September 9 Finger shows fluctuation on dorsum of hand just proximal to index finger and on ulnar side Incision and drainage Finger not so painful, flexion about same Not so tender, no special swelling in palm of hand

September 12 Infection has extended to thenar eminence, tenderness localized to this area Swelling marked, palm not involved

Operation Inserted forceps into cut on dorsum made September 9, forceps fell into direct communication with volar surface of thenar eminence, opened here, pushed forceps then from volar surface through to dorsum between first and second metacarpals, forceps passed through dorsal skin with little or no resistance, drainage inserted

September 15 Subcutaneous abscess has developed in radial region of forearm above wrist and above elbow, and over brachial vessels, incised and drained White blood cells, 18,000

September 24 Temperature, 99° to 101° F

October 14 Temperature has been running 99° to 100° F for last two weeks, index finger swollen to four times its normal size, blue, and evidently there is an osteomyelitis of the proximal phalanx, and a suppurative arthritis of the metacarpo-phalangeal joint

Operation Index finger and head of metacarpal bone amputated, drainage

October 20 Condition of hand much better

Following this the patient improved rapidly, discharged

November 3 Small area of granulation tissue over amputated area, moves thumb and three fingers three-fourths of normal, wrist-joint same, function of all will ultimately be restored

The Spread of Infection Involving the Middle Finger.

Here the finger, lying as it does on the dividing line between the thenar and middle palmar spaces, becomes an extremely interesting subject of study The lymphatic extension has already been touched upon

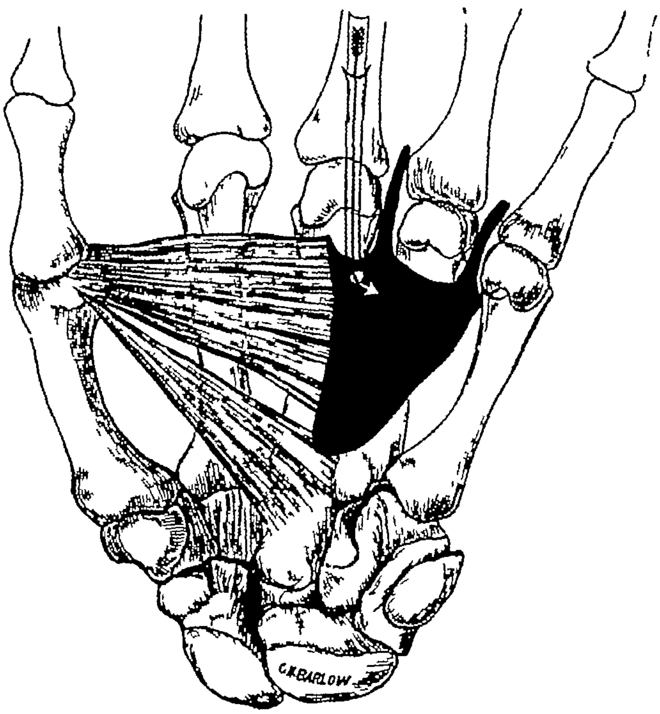


Fig 124 —Schematic drawing made from a dissection of a hand injected from the tendon sheath of the middle finger The mass filled the middle palmar space and extended along the two lumbricals

Extension from the synovial sheath at its proximal end gives positive results experimentally (Experiments 1 and 2), since in every case after involving the loose connective tissue around and superficial to the tendon the mass ruptured into a lumbrical space and extended from this into the middle palmar space. It is to be borne in mind, however, that the lumbrical muscle joining this tendon extends distalwards under the transverse ligament of the heads of the metacarpals, between the index and middle fingers, and that while the tissue intervening

between this muscle and the thenar space is firm, and experimental injections have failed to rupture through, yet, anatomically, it would seem to be possible in some cases Clinical evidence shows that while it does occur this extension is rare For a complete discussion of the extensions from the tendon sheaths, see Chapters IV and XXII Should the infection be a deep-seated accumulation of pus in the cellular tissue upon the dorsum it could

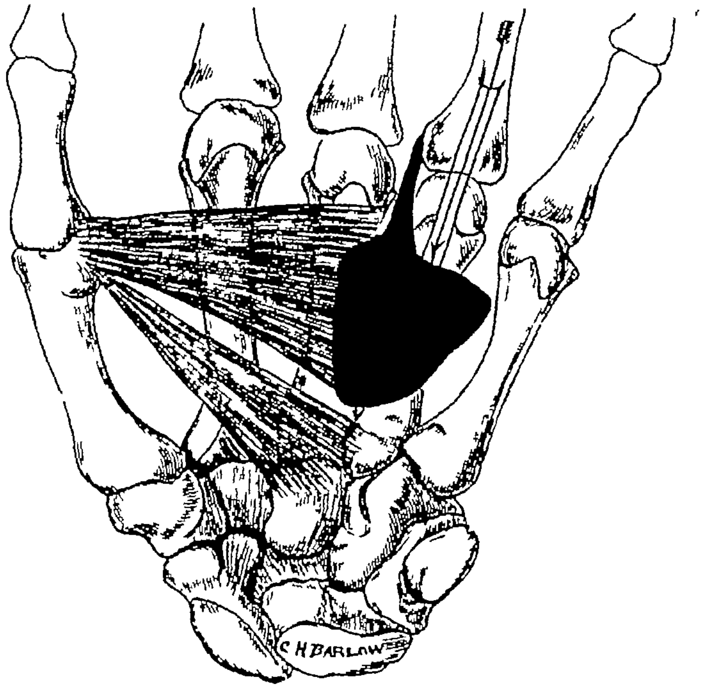


FIG 125 —Schematic drawing made from a dissection of a hand injected along the tendon sheath of the ring finger The mass filled the middle palmar space, with extension along the lumbrical muscle

spread subcutaneously upon the back of the hand, upon the radial side it would pass exceptionally along the lumbrical muscle into the middle palmar space, with the possibility of invading the thenar space, as above noted, upon the ulnar side, if it should spread along the lumbrical muscle, it would go into the middle palmar space (Experiments 26*A*, and 26*B*)

Subaponeurotic infection would be limited to the

phalanx, while osteomyelitis, involving the metacarpal bone, would tend to invade the middle palmar space in front and the subaponeurotic on the back The proximal interphalangeal joint may be involved in neglected tendon-sheath infection The extensions following infection of the metacarpo-phalangeal joint are considered in the chapter with that subject

Exceptionally the tendon sheath of an adjacent finger may be infected by erosion following rupture of pus into a lumbrical canal

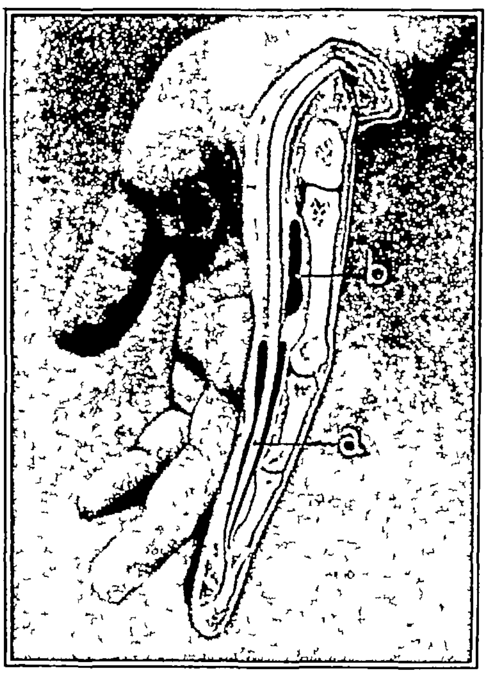


FIG 126 —Relation of the tendon sheath of the ring finger (*a*) to the middle palmar space (*b*) This demonstrates the ease of extension of pus from the tendon sheath to the middle palmar space

THE SPREAD OF INFECTION INVOLVING THE RING FINGER

The extension by the dorsal subcutaneous tissue may be in any direction The connective-tissue spaces at either side of the finger and in the web of the infected hand allow the pus to spread through the fibrous canal surrounding the lumbrical muscles and extend into the middle palmar space (See Experiments 26*A* and 26*B*,

and Fig 3) In making this deduction it should be emphasized again that in a majority of cases pus would be evacuated on the surface before it would burrow through this canal Hence it is only in neglected cases that this complication would ensue, unless extension had taken place by the lymphatic channels which pass through these same canals, a very rare complication in my experience

Suppuration extending from the synovial sheath would enter the middle palmar space (See Experiments 3, 4, 18, 19 and 20, cross-sections, Figs 119 and 120) Primarily, of course, it would lie in the loose connective tissue superficial to the space, spread down along the lumbrical muscles (Fig. 19), especially of the little, ring, and middle fingers, and then, destroying the thin roof of the space, would involve the entire middle palmar space (Fig 125) (For a complete discussion of tendon-sheath extensions, see Chapters IV and XXII)

Osteomyelitis of the diaphysis of the metacarpal could also infect the middle palmar space as well as the subaponeurotic on the dorsum (Case XV) The proximal interphalangeal joint may be involved in neglected synovial sheath infections The extensions from an infected metacarpo-phalangeal joint are considered in the chapter dealing with that subject

Exceptionally the tendon sheath of an adjacent finger may be infected by erosion following rupture of pus into a lumbrical canal

The lymphatic extension has been discussed in the chapter dealing with that subject

Infection Spreading From the Little Finger

Here the lymphatic channels and connective-tissue spaces upon the inner side of the finger could lead into the middle palmar space, although such extension is uncommon. On the outer and dorsal side they would tend to lead into the subcutaneous tissue externally

The synovial sheath, if continuous with the ulnar bursa, would probably rupture earliest in the forearm (See roentgen-ray plate, Fig 22) (For a discussion of this and other extensions from the ulnar bursa, see Chapters IV and XXII) If it did rupture into the hand, or if the synovial sheath of the finger was shut off from the ulnar bursa, and the finger sheath ruptured, it would

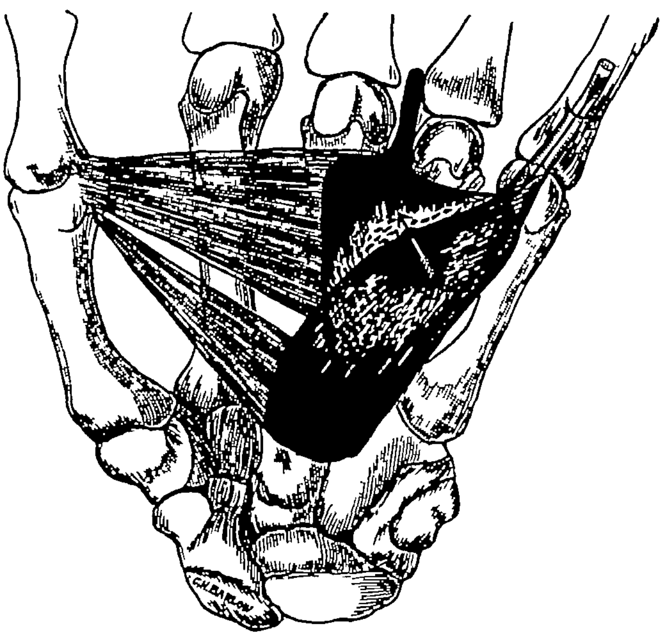


FIG 127 —Schematic drawing made from a dissection of a hand in which the mass was injected along the tendon sheath of the little finger, closure at the upper end of the annular ligament of the ulnar bursa allowed rupture from the ulnar bursa, the mass filling the middle palmar space with extension along one lumbrical muscle

involve the middle palmar space (See Experiments 5 and 6, Fig 127) In any case extension from the ulnar to the radial bursa is probable It might be mentioned here that Chevalet and Dolbeau maintain that a rupture of the sheath is not necessary to extension, but that this can take place from the sheath by lymphatic extension; they adduce a postmortem examination in support of their contention This however, is an academic question,

since the same space would be involved by the extension, and the clinical findings would be identical

If an osteomyelitis of the fifth metacarpal be present the hypothenar space would be involved upon the volar surface and the subcutaneous tissue dorsally. (See cross-sections, Figs 119 and 120) Involvement of the proximal interphalangeal joint may occur in neglected tendon-sheath infection, less often, however, than in the other fingers Extensions from the metacarpo-phalangeal joint are considered in the chapter dealing with that subject.

Exceptionally the tendon sheath of the ring finger may be infected by erosion following the rupture of pus into the lumbrical canal

Infections Beginning in the Palm and Dorsum

If infection is implanted in the middle palmar or thenar spaces through injury, an abscess will develop in these spaces Extensions from these spaces are described when discussing abscesses of these spaces If implanted in the superficial thenar or hypothenar area, local abscesses will develop without entering the palmar or thenar spaces If the infection develops at the distal part of the palm in the subcutaneous tissue or in the lumbrical space, *i e*, a "frog felon," "collar-button" abscess (see Chapter XII), and if extension occurs it will generally be to the dorsum between the bases of the fingers, although occasionally proximally along the lumbrical canals into the middle palmar space, if between the little and ring fingers or ring and middle fingers It may extend into the thenar space if between the middle and index fingers In the central part of the palm it is not possible for large abscesses to develop between the skin and the palmar fascia, owing to their intimate association If the infection is implanted superficial to the tendons and under the palmar fascia, the abscess will soon extend to the middle palmar space.

Occasionally we see sloughing of the palmar fascia in these cases

Lymphatic infections in the central part of the palm may involve the deeper part of the hand although I have never seen it occur (Fig 50) At the sides the infection pursues the shortest course to the back of the hand, where abscesses may develop subcutaneously At the proximal end of the palm secondary lymphatic abscesses may develop subcutaneously above the transverse carpal ligament (See Chapter XXII)

When the primary focus develops upon the dorsum, if it be a localized abscess, it will be either in the subcutaneous or subaponeurotic spaces If extension takes place by contiguity or lymphatic channels, the secondary abscesses lie upon the dorsum of the forearm or the glandular area at the elbow and axilla

RÉSUMÉ

Infection may spread in one of three ways· by a lymphatic canal, by a fascial space, or through a synovial sheath

Infection involving the *thumb*, if it spreads by the fascial space, will readily come to the surface If by the synovial sheath, it will rupture into the major forearm space or exceptionally into the thenar space

If the infection in the *index finger* spreads by the fascial spaces, the pus will lie in the connective tissue at the web of the index and middle finger, whence it may spread along the lumbrical muscle into the palm

In any other part, the pus will lie underneath the skin and will soon come to the surface

When the pus extends by way of the synovial sheath it may spread to the thenar space, either by direct rupture into the space or by an intermediate involvement that embraces the lumbrical space on either side, less often

it will involve the proximal interphalangeal joint or come to the surface

The proximal interphalangeal joint will be involved more often than the metacarpo-phalangeal joint

If the *middle finger* be involved and the pus spreads by the fascial space, it will come to the surface or lie in the connective-tissue space at the web, whence it may involve the middle palmar or thenar space by way of the lumbrical canal It will generally come to the surface, however If it spreads by way of the tendon sheath, it will ordinarily involve the middle palmar space but may involve the thenar space In the latter instance, the course is by the intermediate channels along the lumbrical space between the index and middle fingers In the former case it is by way of the lumbrical canal between the middle and ring fingers The proximal interphalangeal joint will at times become involved

If the pus spreads along the *ring finger* by way of the fascial space, it will be liable to come to the surface or involve the connective-tissue space on either side of the web, where it will ordinarily rupture externally but may pass along either lumbrical canal into the middle palmar space

If the tendon sheath be involved, pus will invade the middle palmar space either directly or by rupture and extension along the lumbrical canal on either side It may involve the proximal interphalangeal joint or come to the surface

If infection spreads along the *little finger* by way of the fascial space, the pus will either come to the surface or lie in the connective-tissue space of the web between the ring and little fingers, from whence it will probably come to the surface but may spread along the lumbrical canal into the middle palmar space

If the pus spreads by the tendon sheath it will ordinarily extend into the ulnar bursa and from thence may involve

the tissue in the forearm underneath the flexor profundus (major forearm space) or rupture into the middle palmar space It generally involves the radial bursa after a day or two It may be confined in the tendon sheath of the little finger and rupture into the lumbrical space between the little finger and ring finger and thence involve the middle palmar space

In infection of any finger tendon sheath it is always possible for the adjacent tendon sheath to become involved by erosion after rupture of the pus into the intervening lumbrical canal

If pus spreads from the palm and is superficial to the palmar fascia, it will develop small abscesses which will rupture quickly We may see a large abscess superficial to the tendons due to sloughing of the palmar fascia If in the distal part of the palm in the connective tissue at the web or in the lumbrical space, pus will either come to the dorsal surface at the web or enter the lumbrical canal and pass into either the middle palmar or thenar space varying with the area involved

If in the *middle palmar space*, pus may extend into the lumbrical canals to the web and possibly rupture through the intervening tissue into the thenar space

Thenar-space abscess will ordinarily come to the surface on the dorsum, between the thumb and index finger, or may rupture into the middle palmar space

If in the *hypothenar space*, the pus will ordinarily come to the surface upon the dorsum

CHAPTER XXI.

PATHOLOGY OF TENDON-SHEATH AND FASCIAL-SPACE ABSCESSES.

THE discussion is here limited to changes in the tendons, tendon sheaths, and fascial spaces. The pathology of bone changes, arthritis, and secondary sequelæ in the hand and forearm will be considered later.

A classification of the changes incident to tenosynovitis may be made as follows.

Primary· *A* Changes while the infection is limited to the sac (1) Contents of sac, serum, tendon. (2) Wall of sac (3) Circulation, lymphatics with edema

B. When rupture of the sac occurs· (1) Involvement of the fascial spaces, (*a*) hand, (*b*) forearm (2) Involvement of the nerves (3) Involvement of joints. (4) Involvement of bones.

Secondary. (1) Tendon adhesions. (2) Ankylosis of joints. (3) Persistent edema and hyperplasia of cellular tissue, scar contraction with subsequent atrophy (4) Chronic osteomyelitis.

The changes occurring in the section under "primary *B*" will be discussed under fascial-space abscesses following, and the "secondary" changes will be discussed in detail in later chapters, dealing with the complications and sequelæ of infections (see Chapter XXVI).

THE TENDON SHEATH PROPER.

Anyone who has had occasion to open the acutely inflamed tendon sheath has been surprised at the rapid change which has taken place. The changes are comparable to a pressure necrosis, but whether due to the

great toxicity of the streptococcus infection or the great edema about and the effusion into the sheath, shutting off the blood supply, may be a question

The serum in the sac in early stages of the more acute cases is normally scanty in amount and only slightly tinted. Later the consistency varies from a slightly slimy fluid to a thick pus While in the more acute varieties the amount may at times be very great, it soon ruptures, and on operation we may find little or much in the sac, in the more chronic type we frequently find a large amount of thick, creamy pus, even though rupture has ensued

The wall of the sac is congested and edematous with the exception of the part under the anterior annular ligament where the pressure is great Here necrosis, not alone of the sheath, but also of the tendons and even the median nerve, is prone to occur. While we may find the synovial lining clear and unchanged, we generally find it cloudy with whitish-yellow spots of beginning necrosis, or we may even early find the entire wall seminecrotic Even in these cases we are often surprised at the reparative possibilities after drainage is instituted

The tendons themselves are swollen, but retain their glistening synovial covering for some time At the wrist, however, the tendons show the result of compression by the non-distensible transverse carpal ligament, being pale and compressed, this is accentuated by the swelling which has occurred both above and below the ligament If the patient has been left untreated for too long a time, the tendons lose their glossy covering and, becoming fragmented and necrotic, are extruded, appearing like grayish strings of connective tissue

While the entire hand partakes of the edema, it is in the finger involved that the most extensive and persistent changes occur Especially in the neglected cases do we see a most extensive exudation of inflammatory

elements which persist for weeks after the acute process has subsided, this is followed by an atrophy of the entire finger, ankylosis of joints and impaired nerve function, which aids materially in preventing a proper use of the finger even if the tendon is not destroyed The adhesions between the sheath and the tendon combined with these serious sequelæ make a bad prognosis as to function in the neglected cases, often ending in the characteristic claw-hand

THE FASCIAL-SPACE ABSCESSES

In discussing the essential pathology it should be remembered that we are restricting ourselves strictly to that phase of the subject having a relation to the anatomical and experimental studies preceding The pathology of acute abscess formation in connective tissue is too well known to merit discussion here Moreover, to do more than mention the arthritis in the wrist, the osteomyelitis of the metacarpals, and the destruction of tissue and fistulous sequelæ would be out of place, since these will be discussed in the chapters dealing especially with these subjects We should, however, draw attention to certain consequences of suppuration in the individual spaces

Let us ask ourselves what would be the after-results of infection of the middle palmar space alone, the tendon sheath not being infected We shall divide them into primary and secondary, and under the caption of primary, attention should be drawn to the fact that the scar tissue following such a process would involve particularly the tendons of the middle and ring fingers, with the lumbrical muscles of the middle, ring, and little fingers Consequently, it is in these fingers that we would expect to find the most persistent adhesions and contraction, and it is in consequence of the disturbed circulation in the blood-vessels going to these fingers that long persisting edema

and nutritional changes occur, augmented somewhat, probably, by impaired nerve supply

Secondary sequelæ are noted in the associated edema and changes in the index finger and to a lesser degree in the thumb, and while these are severe, they are not of such high grade as in other digits These changes are most marked in the index finger, and are due to the juxtaposition of the tendons and the intimate relation of the circulation The ulnar bursa, with its contained tendons, is adjacent to the area of infection, consequently, there is the probability of a low grade of inflammation within with consequent impairment of tendon function decreasing in intensity from the little finger. The correlation of movement between the tendons determines approximately the same position for the index finger as the others This constant position, associated with an effusion into the joints, leads to adhesions of the articular surfaces in all the fingers Since the tendon of the thumb is well separated from the site of infection this digit is but slightly affected Should the process extend to the thenar area, the index finger would then be in the same condition as the other fingers On the other hand, if the infection were primary in the thenar space, the most disastrous changes would ensue in the index finger, while the other three fingers would suffer only the secondary changes, but fortunately not so severe since the three ulnar tendons would not be contiguous to the infection This is owing not alone to this factor, but also to the fact that thenar abscesses are sooner recognized and more perfectly drained, consequently the process is not so disastrous

Should the subaponeurotic space be involved primarily, or by an extension from the palmar space, or multiple ill-advised incisions be made as is too often done, adhesions take place, and the whole sheet becomes more or less immobile as a consequence of the involvement of all the extensor communis tendons. Should proper treatment

be resorted to, even after a number of days, all of these changes will disappear and a perfectly functionating hand be assured.

The pathology in the tendons and median nerve under the anterior annular ligament has serious consequences. One notes early that these are inflamed and swollen both proximal and distal to the ligament while the parts under the ligament are more or less white and only slightly swollen, due to the pressure from the non-distensible volar ligament Later due to this same pressure there is an early necrosis, reaching its highest degree in the long neglected cases where upon operation one finds a complete destruction of both nerve and tendons at this site, replaced by dense connective tissue if healing has occurred

The pathological processes following involvement of the major forearm space also have serious consequences The most serious are those due to the extension of the infection along the median nerve and the ulnar nerve and artery The early inflammation of the nerves gives rise to pain At a later stage erosion of the artery may take place with secondary hemorrhage and still later the scar tissue contracting about the artery and the nerves impair seriously both nutrition and function

and nutritional changes occur, augmented somewhat, probably, by impaired nerve supply.

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Should the subaponeurotic space be involved primarily, or by an extension from the palmar space, or multiple ill-advised incisions be made as is too often done, adhesions take place, and the whole sheet becomes more or less immobile as a consequence of the involvement of all the extensor communis tendons Should proper treatment

the prick of a needle, or there may be no history of injury. The pain has increased in severity after a day or two Systemic symptoms of infection may be present. The finger and the corresponding side of the hand at least are edematous In addition to the tumefaction in the infected finger the adjacent digits are swollen The back of the hand particularly is edematous The whole hand is slightly tender to superficial palpation. The fingers are all slightly flexed Now, how shall the differential diagnosis be made? Press deeply and firmly in all parts of the hand and fingers, the patient will volunteer the information that all points hurt, but if the tendon sheath is involved, pressure upon it throughout its course causes an immediate and involuntary expression of pain, and while before the patient has allowed his hand to remain passive in yours, he will now attempt to withdraw it involuntarily, and there is no doubt in your mind of the exquisite tenderness over this area *If this tenderness is outlined by the extent of the sheath, your diagnosis is nearly made* As a matter of fact, the greatest tenderness is generally complained of on deep pressure at the proximal end of the finger sheaths in the palm of the hand, just over the metacarpo-phalangeal articulation I have seen a lacerated wound on the back of the finger, which was inflamed and naturally tender, show much less sensitiveness than the infected sheath on the opposite side of the finger where there was no injury Now make passive extension of the finger, and the patient immediately complains of severe pain along the tendon sheath, very often again most marked at the site of the metacarpo-phalangeal articulation This is a valuable symptom The flexion of the fingers is of less importance and is probably due to several factors—the arthritis in the finger-joints, possibly irritation of the adjacent filaments of the median or ulnar nerve and, again, possibly because it lessens the tension upon the tendon. The finger is generally held rigid in

CHAPTER XXII

THE SYMPTOMS, SIGNS, AND DIAGNOSIS OF TENOSYNOVITIS AND MAJOR FASCIAL-SPACE ABSCESSES

THE SYMPTOMS, SIGNS AND DIAGNOSIS OF ACUTE SUPPURATIVE TENOSYNOVITIS

TO diagnosticate the onset of involvement of the tendon sheaths is one of the most difficult problems in surgery, and yet, withal, one of the most important I know of no place where calm judgment is more required, since the symptoms and signs are of all degrees It must be said, however, that more extensive experience has taught me that it is generally better to err by making an unnecessary incision than by failing to operate where it is needed

The four cardinal symptoms and signs are

1 *Excessive tenderness over the course of the sheath, limited to the sheath.*

2 Symmetrical enlargement of the whole finger

3 Excruciating pain on extending the finger, most marked at the proximal end

4 Flexion of the finger

These symptoms are seen to be only a difference in degree from those found in any infection of the hand, but when sought for in an intelligent manner there is not much difficulty in differentiating the conditions

A patient applies to the physician with what is evidently a serious infection If there has been a crushing injury, the probability of an infected tendon sheath is great, on the other hand, it most often arises from simple injuries, as, for instance, a slight laceration from a tin can or from

the prick of a needle, or there may be no history of injury The pain has increased in severity after a day or two Systemic symptoms of infection may be present. The finger and the corresponding side of the hand at least are edematous In addition to the tumefaction in the infected finger the adjacent digits are swollen The back of the hand particularly is edematous. The whole hand is slightly tender to superficial palpation The fingers are all slightly flexed Now, how shall the differential diagnosis be made? Press deeply and firmly in all parts of the hand and fingers; the patient will volunteer the information that all points hurt, but if the tendon sheath is involved, pressure upon it throughout its course causes an immediate and involuntary expression of pain, and while before the patient has allowed his hand to remain passive in yours, he will now attempt to withdraw it involuntarily, and there is no doubt in your mind of the exquisite tenderness over this area *If this tenderness is outlined by the extent of the sheath, your diagnosis is nearly made* As a matter of fact, the greatest tenderness is generally complained of on deep pressure at the proximal end of the finger sheaths in the palm of the hand, just over the metacarpo-phalangeal articulation. I have seen a lacerated wound on the back of the finger, which was inflamed and naturally tender, show much less sensitiveness than the infected sheath on the opposite side of the finger where there was no injury Now make passive extension of the finger, and the patient immediately complains of severe pain along the tendon sheath, very often again most marked at the site of the metacarpo-phalangeal articulation This is a valuable symptom The flexion of the fingers is of less importance and is probably due to several factors—the arthritis in the finger-joints, possibly irritation of the adjacent filaments of the median or ulnar nerve and, again, possibly because it lessens the tension upon the tendon. The finger is generally held rigid in

CHAPTER XXII

THE SYMPTOMS, SIGNS, AND DIAGNOSIS OF TENOSYNOVITIS AND MAJOR FASCIAL-SPACE ABSCESSES

THE SYMPTOMS, SIGNS AND DIAGNOSIS OF ACUTE SUPPURATIVE TENOSYNOVITIS

TO diagnosticate the onset of involvement of the tendon sheaths is one of the most difficult problems in surgery, and yet, withal, one of the most important I know of no place where calm judgment is more required, since the symptoms and signs are of all degrees It must be said, however, that more extensive experience has taught me that it is generally better to err by making an unnecessary incision than by failing to operate where it is needed

The four cardinal symptoms and signs are·

1 *Excessive tenderness over the course of the sheath, limited to the sheath*

2 Symmetrical enlargement of the whole finger

3 Excruciating pain on extending the finger, most marked at the proximal end

4 Flexion of the finger

These symptoms are seen to be only a difference in degree from those found in any infection of the hand, but when sought for in an intelligent manner there is not much difficulty in differentiating the conditions

A patient applies to the physician with what is evidently a serious infection If there has been a crushing injury, the probability of an infected tendon sheath is great, on the other hand, it most often arises from simple injuries, as, for instance, a slight laceration from a tin can or from

there streptococci This type is prone to produce early rupture and extension into the connective-tissue spaces.

The spontaneous pain, which was at first severe, grows less as the edema develops, and this lessening of pain may delude the surgeon into believing that the process is subsiding The arm seems to "fall asleep," as the patient expresses it Paresthesia, with creeping and itching sensations, may be present, and especially after rupture of the sheath the tenderness may subside to a considerable degree, leading the surgeon to an early erroneous conclusion

The Symptoms, Signs and Diagnosis of Extensions From Tendon-sheath Infections Beginning in the Little Finger.

An infection of the sheath of the tendon in the little finger may be localized to the finger Extensions to other areas are probable, however (Fig 128). The following are the most common (1) *The ulnar bursa,* (2) the *radial bursa,* (3) *the forearm* (major forearm space), (4) fascial spaces in the hand, (*a*) middle palmar space, (*b*) lumbrical space, (5) osseous involvement, middle phalanx, (6) joints, proximal interphalangeal, wrist, (7) rupture to the surface.

Extension to the Ulnar Bursa —In the fulminating type, where the opening between the ulnar bursa and the sheath in the little finger is present, the infection extends rapidly throughout the bursæ It should be noted here that the frequency of extension from the one to the other is greater than the anatomical opening would explain, we are therefore led to conclude that the opening is present much more frequently than is stated, or there is some other method of extension, possibly by the lymphatics

The extension is often difficult to diagnosticate It is marked by the development of edema in the hand, especially upon the dorsum. A general fulness in the

that position and a difference is readily seen between the simple flexion occurring in the adjacent swollen fingers and the rigid flexion of the infected finger So marked is this that often one is able to diagnosticate an extension into the palmar sheath, for instance, from the little finger sheath, since in that case the character of the flexion changes at once in the fingers supplied by these tendons which pass through the ulnar bursa Mauclaire has described a claw-hand position, but I have not found it to be characteristic of acute inflammation, but to be rather the evidence of an old chronic untreated tenosynovitis. *The entire finger shows a symmetrical enlargement.* This is the essential diagnostic point in differentiating tendon-sheath infection from felons.

There are two clinical types to be differentiated· First, that variety in which the infection is a local one, generally of staphylococcic origin, commonly following lacerated wounds Here we have a local infection beginning slowly, plastic adhesions may be present, limiting the infection to a particular part There is some general reaction, but the local evidences of inflammation are marked. A second type is that in which the injury is generally a slight one, a pin prick or an insignificant cut It is generally of streptococcic origin The infection is carried to the sheath by lymphatics. The pain is severe, and within a few hours the finger is greatly swollen, red, and exquisitely tender. The evidences of toxemia are present early but the red lines running up the arm, indicative of a lymphangitis, are absent, although they may have been present early. (See Case XXV) This type, not having a tendency to plastic adhesions, spreads rapidly throughout the entire communicating system of sheaths. These are distended with a fluid, at first only cloudy, but rapidly becoming purulent, and on examination we find thick pus with fragmented nuclei, due probably to the virulent toxins, and here and

palm occurs at the same time, but is not so conspicuous, owing to the palmar fascia. This also diffuses the swelling so that it is not accurately limited by the outline of the ulnar bursa Moreover, the surrounding edema tends to confuse the picture

One very seldom finds in acute infections of the bursæ so great a collection of pus within the latter as to cause a purely mechanical swelling of such extent that one can easily see it from the outside. The wall of the bursa, before an extensive formation of exudate, is necrotic and has usually permitted the accumulation to escape into the surrounding connective-tissue spaces

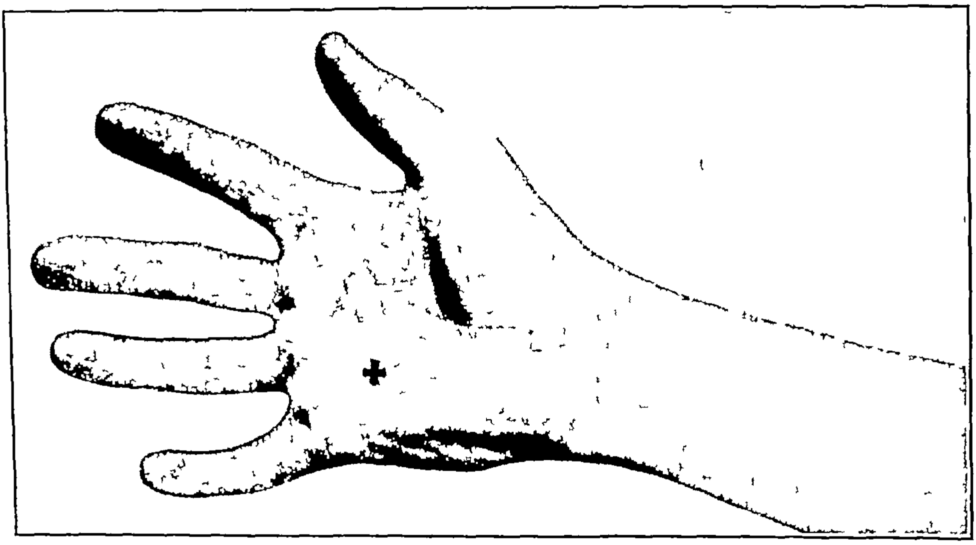


FIG 129 —Point of greatest tenderness in ulnar bursal infection

The edema and swelling are of such a character that fluctuation can seldom be definitely elicited. One should never wait for this symptom before operating In chronic tenosynovitis, such as tuberculous infection, the symptom is of undoubted value

The most conspicuous and valuable sign is the extension of the exquisite tenderness to the area involved and especially at a point just proximal to where the distal flexion crease in the palm joins the hypothenar eminence (Fig 129) It should be remembered that this is absent after a few days.

palm is found, but the palmar concavity is still present. On the flexor surface the greatest swelling is just proximal to the annular ligament. This is not necessarily due to

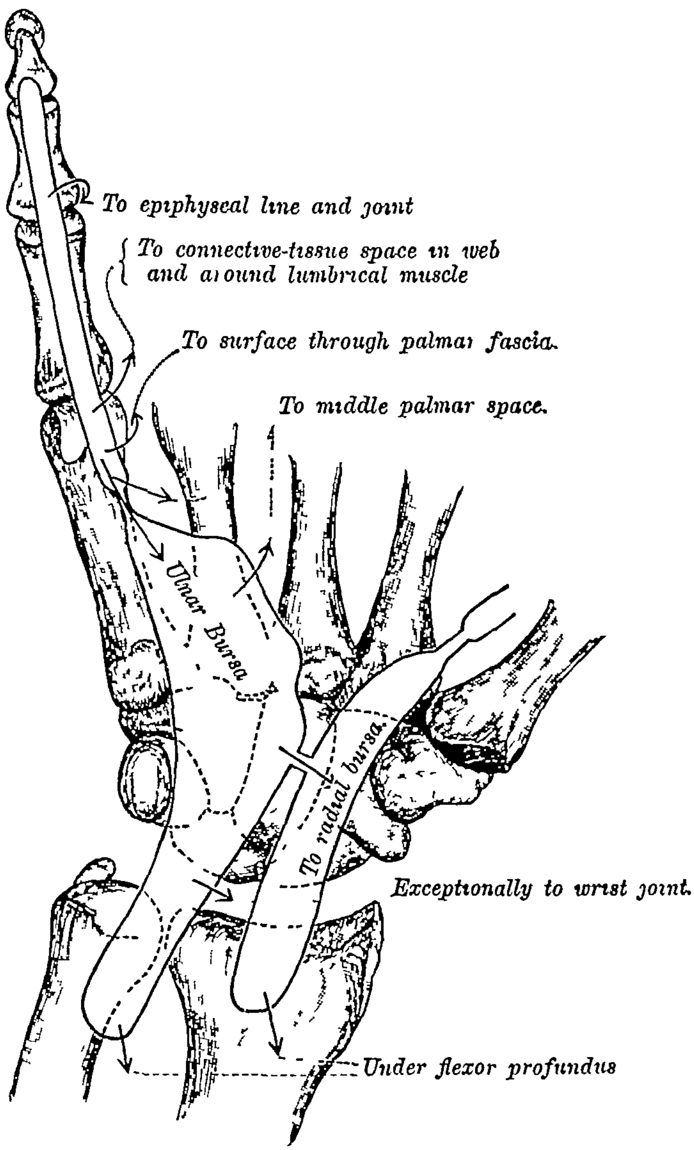


FIG 128 —Schematic drawing, showing the various probable extensions from an infection of the tendon sheath of the little finger Exceptionally the tendon sheath of the ring finger may be infected by erosion from a rupture of pus into the intervening lumbrical canal

the rupture of the sheath here, but to the looseness of the tissues which permits of distention This swelling is accentuated by contrast with the non-distensible transverse carpal ligament distal to it The swelling in the

palm occurs at the same time, but is not so conspicuous, owing to the palmar fascia. This also diffuses the swelling so that it is not accurately limited by the outline of the ulnar bursa Moreover, the surrounding edema tends to confuse the picture

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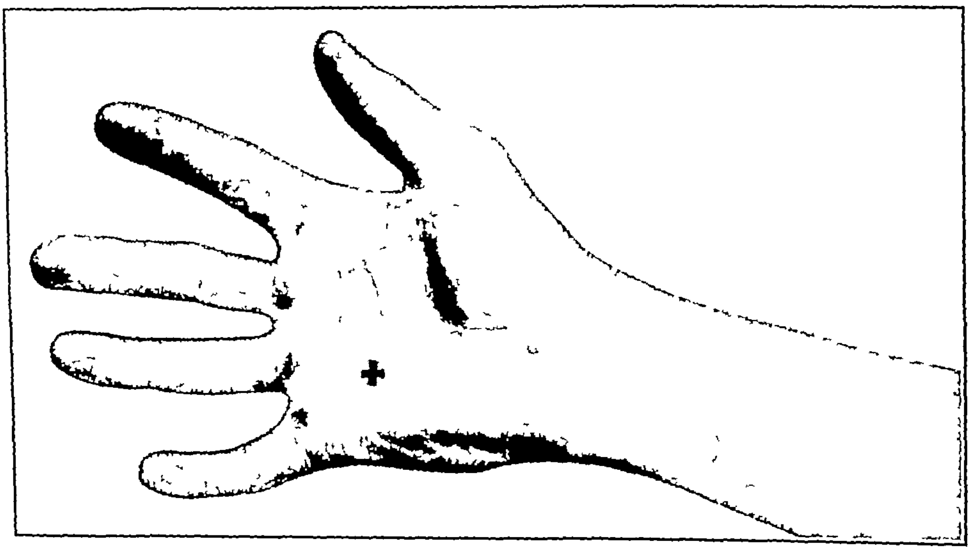


FIG 129 —Point of greatest tenderness in ulnar bursal infection

The edema and swelling are of such a character that fluctuation can seldom be definitely elicited One should never wait for this symptom before operating In chronic tenosynovitis, such as tuberculous infection, the symptom is of undoubted value.

The most conspicuous and valuable sign is the extension of the exquisite tenderness to the area involved and especially at a point just proximal to where the distal flexion crease in the palm joins the hypothenar eminence (Fig 129) It should be remembered that this is absent after a few days.

The wrist becomes fixed, the thumb shows tenderness to pressure, and particularly on passive movement is the sensitiveness noted It is readily seen of how much importance this latter symptom is in diagnosticating an extension to the ulnar bursa from the little finger. We note that while at first the symptoms are limited to the little finger and slight changes in the ring finger because of its juxtaposition, all at once the thumb begins to show the characteristic signs of contracture and tenderness, while the index and middle fingers remain unchanged except for the increase of pain on passive extension explained above This sensitiveness of the thumb may be due either to the juxtaposition of the sacs or to a real extension into its sheath

At first there may be a diffuse redness of the palm and dorsum, but it rapidly gives place to a whitish or even cyanotic hue Above the wrist, however, the tissue generally takes on a marked red color, which later becomes violaceous The temperature and pulse may not be of any diagnostic importance Ordinarily, after the infection has lasted a few days and the walling-off process has begun, the temperature is that of the local accumulation of pus and varies with the freedom of drainage In the first few days, however, the systemic absorption bears no relation to the abscess formation and cannot be relied upon for diagnostic purposes

Extension to the Radial Bursa —This is diagnosticated as following an ulnar bursitis by the increased swelling and tenderness in the thenar eminence and along the sheath with the associated symptoms described above. The tumefaction of the thenar area is not that of abscess in the thenar space Forssell states that this extension occurred in 6 out of 29 cases coming under his observation —average age, fifty to fifty-eight years, 23 cases remained confined to the ulnar bursa—average age, thirty-six to thirty-nine years. In my own experience the percentage

of extension is far greater   It is evident that this percentage will vary with the stage of diagnosis and operation   I believe it has occurred in fully 50 to 75 per cent of cases seen in consultation   So much has this been impressed upon me that in a definite ulnar bursal infection of forty-eight hours' duration this extension should be assumed to be present and exploratory incisions made

Extension to the Forearm —By this we mean a rupture from the proximal end of the sheath and an extension into the *major forearm space*   As I have already pointed out, the pus passes between the flexor profundus and the pronator quadratus to the area between the former and the interosseous membrane, and at about the middle of the area it passes more superficially and to the ulnar side along the ulnar artery and nerve   I have had opportunity to verify this area of extension many times in cases I have operated upon, and have also seen it in one fatal case I had an opportunity to dissect (Case X)   This extension is characterized by a brawny induration that should not be confused with the softness of an edema   No fluctuation should be expected, since the accumulation lies too deeply   This extension is marked also by the loss of the relative swelling immediately above the transverse carpal ligament due to the distended upper end of the sheath before rupture   This swelling is not any less, but that of the arm is greater   The tenderness may become less, so it cannot be depended upon as a symptom   The redness is generally greater, and spontaneous pain, while at first marked, rapidly subsides   *In a definite ulnar or radial bursal infection that has lasted forty-eight hours such an extension should be assumed and an ulnar forearm incision made*   No harm will be done if pus is not found

At this time some pus may accumulate subcutaneously above the wrist, due to lymphangitis, and lead to the supposition that there is no pus under the tendons, so that valuable time is lost.

EXTENSION TO THE LUMBRICAL AND PALMAR SPACES —After these mentioned above the most common extension is into the lumbrical and palmar spaces. The involvement of the adjacent lumbrical space occurs so frequently as to keep one continually on his guard, since from this involvement of the tendon of the adjacent finger or palm may occur. It is characterized by tenderness, swelling, and pain at the site. The tissue between the fingers on the dorsum of the corresponding web is generally swollen and red, the side of the adjacent ring finger is often red and tender I begins to swell slightly, and by extension the tendon sheath of that finger may exceptionally become involved with the characteristic symptoms and signs In involvement of the lumbrical space alone, the swelling of the area involved is marked. The middle palmar space is in neglected cases commonly involved, either by extension along the lumbrical space or from rupture of the ulnar bursa directly The thenar space is never primarily involved in the little finger infections Involvement of the middle palmar space is characterized by a slight bulging of the palm replacing the normal concavity The symptoms and signs of this complication, as well as those observed in osseous and joint involvement, will be discussed in the subsequent pages Mention should also be made of the frequency, in neglected cases, of rupture of the sheath through the palm to the surface at the proximal end of the finger sheath

THE SYMPTOMS, SIGNS AND DIAGNOSIS OF EXTENSIONS FROM TENDON-SHEATH INFECTIONS BEGINNING IN THE INDEX, MIDDLE AND RING FINGERS.

Involvement of the tendon sheaths of the index, middle or ring fingers presents the cardinal symptoms and signs already described The paths of extension, however, are different from those seen in infections of the little finger sheath The most common extension is into the lum-

brical space on either side, from here the pus extends into either the major palmar spaces as noted below, or to the dorsum in the web The fingers differ somewhat in the



FIG 130 —Tenosynovitis of middle finger, with middle palmar abscess—result of cutting finger on steel tag (Mock)

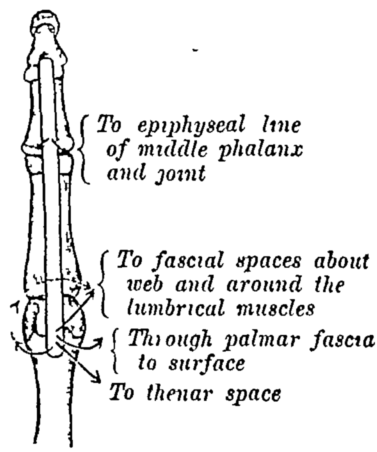


FIG 131 —Schematic drawing, showing probable extensions from an infection of the tendon sheath of the index finger Exceptionally the tendon sheath of the middle finger may be infected by erosion following rupture of pus into the lumbrical canal

method of their extension into the palm, as will be seen by noting the accompanying drawings (Figs 131, 132 and 133) The middle and ring fingers drain into the middle palmar space, and the index finger into the thenar space

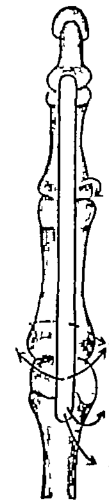


FIG 132 —Schematic drawing, showing probable extensions from infection of the tendon sheath of the middle finger Exceptionally the tendon sheath of an adjacent finger may be infected by erosion following rupture of pus into a lumbrical canal



FIG 133 —Schematic drawing, showing probable extensions from the infection of the tendon sheath of the ring finger Exceptionally the tendon sheath of an adjacent finger may be infected by erosion following rupture of pus into a lumbrical canal If it extends to the little finger and ulnar bursa, severe complications may ensue

In common with the little finger these also present less often involvement of the middle phalanx, the proximal interphalangeal joint, and rupture to the surface most

infrequently of all It should be remembered that exceptionally following rupture of pus into a lumbrical canal the tendon sheath of an adjacent finger may be infected by erosion (See Case XIV) Involvement of the ulnar bursa from the ring finger should be watched for especially This serious complication not being expected may be overlooked When it occurs the symptoms and signs enumerated when discussing ulnar bursitis will be found

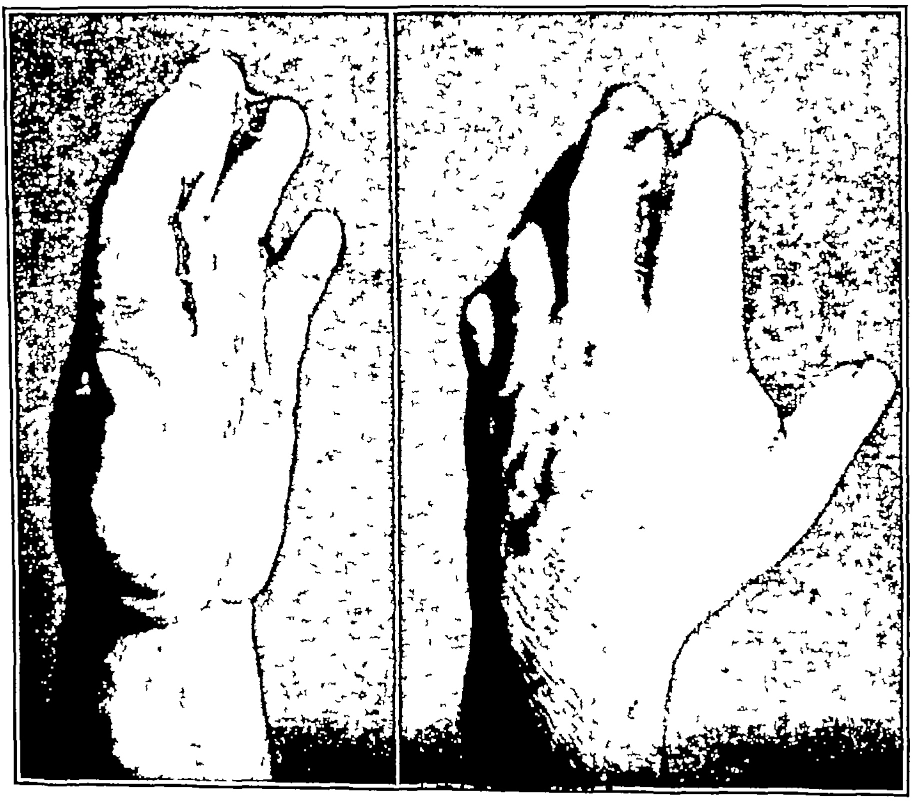


FIG 134 —Suppurative tenosynovitis of the middle finger with extension into the middle palmar space Note that the concavity of the palm is lost

As illustrating the extension from the index finger into the thenar space, with no involvement of the middle palmar space, I record the case of Miss M, seen with Dr Besley at the Post-Graduate Hospital. The probability of this extension was pointed out by myself experimentally some time previous to the opportunity to

observe a clinical case proving the assumption Fig. 135 shows such a condition.

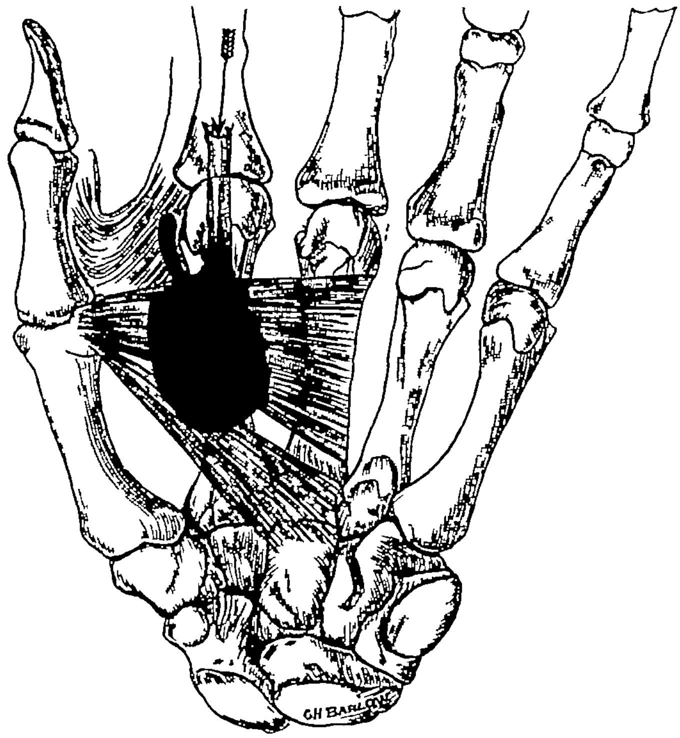


FIG 135 —Schematic drawing made from a dissection of a hand in which the injection was made along the tendon sheath of the index finger Mass filled the thenar space and extended along the lumbrical muscle

CASE XVIII —Seen in consultation with Dr F A Besley at the Post-Graduate Hospital

History —Patient stated that twenty-four hours before she had run a needle in the distal phalanx of the index finger of the right hand. Inside of seven or eight hours the pain became severe and she arrived at the hospital complaining of excessive pain and tenderness

Examination —Patient's temperature, 102 5° F , pulse, 100 Index finger seemed to be slightly swollen Tenderness was present over the entire finger and the lower portion of the hand on the radial side without localization at any point The glands in the axilla were swollen, those in the elbow not involved No lymphatic lines seen.

Treatment —A diagnosis of lymphatic infection, possibly tenosynovitis, was made and hot boric dressings applied

The next morning the temperature had fallen markedly and the patient insisted on leaving the hospital She returned in two days

with all the evidences of acute systemic infection—temperature, 102° F, headache and sleeplessness Locally the finger presented about the same appearance as when seen two days before, except that there was a slight increase in swelling and the thenar space from the adduction crease in the thumb seemed to be ballooned out from the remainder of the hand The concavity of the palm was still present

Diagnosis of previous tenosynovitis in the index tendon sheath, with rupture at its proximal end and involvement of the thenar space was made

On operation pus was found to be present, there was a very large accumulation in the thenar space, which was drained by through-and-through drainage from the palm to the dorsum between the metacarpal bones of the index finger and thumb The tendon sheath of the index finger was opened throughout its extent

Course—Patient's temperature rapidly subsided and in two or three days was normal or 99° F Infection of the thenar space had entirely subsided at the end of seven days, and the wounds healed promptly The opening in the tendon sheath of the index finger, however, was present for four weeks, necessitating repeated dressings

Result—Recovery with all functions except flexion of the distal phalanges of the index finger

The Symptoms, Signs and Diagnosis of Extensions From Tendon-sheath Infection Beginning in the Thumb and Radial Bursa

The gravity of tenosynovitis of the flexor pollicis longus of the thumb has long been recognized The symptoms and signs common to the other digits previously discussed are found here except that the tenderness over the bursa is not marked due to the fact that it is covered by the thenar muscles To diagnosticate the extension into the radial bursa and then to the ulnar bursa is more difficult (Fig 136). Let us suppose the thumb has been the seat of the primary infection This member is very painful, the index finger is slightly sensitive, and the other three fingers hardly at all After a time, if the infection spreads throughout the sheath, all the fingers become more painful to passive extension, and should the infection pass over into the ulnar sheath all the fingers become flexed and the pain severe upon extension of the tendons, most

marked, however, in the little finger In other words, it assumes the character of an ulnar bursal infection. The tenderness over the sheath is not always so marked in secondary involvement, however, due possibly to the previously developed edema *The diagnosis of extension to the ulnar bursa is ordinarily confirmed by the presence of a*

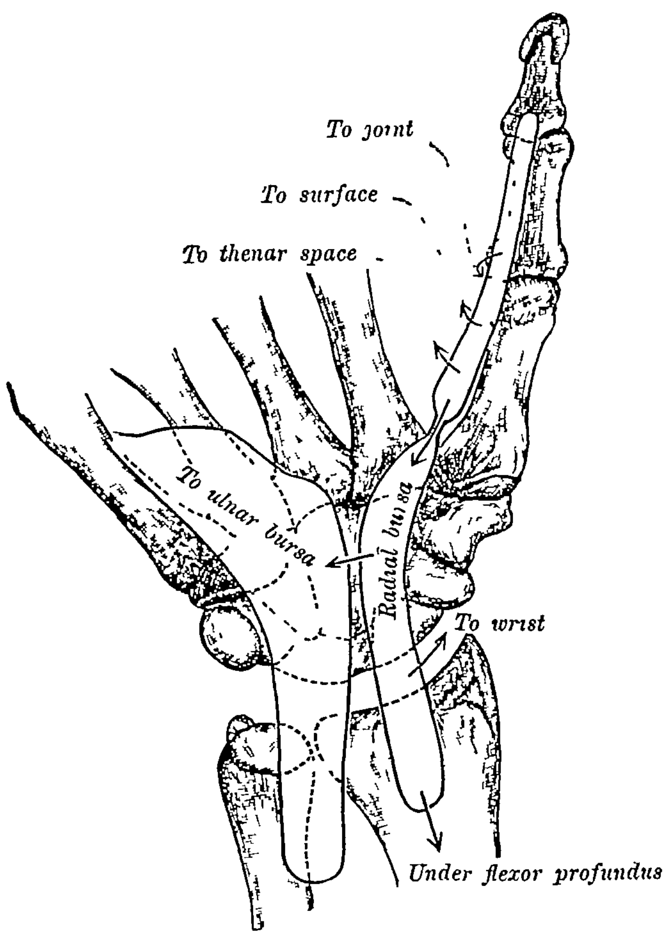


FIG 136 —Schematic drawing, showing probable extensions from infection of the tendon sheath of the thumb (Flexor pollicis longus)

point of tenderness just proximal to the point where the distal flexion crease of the palm crosses the ulnar bursa. This area, about ¼ inch in diameter, is nearly always distinctly tender in contradistinction to the remainder of the palm, in fact it is more tender than is the area over the radial bursa Forssell's statistics show that 23 out of 27 cases

of radial bursitis extended to the ulnar bursa—average age forty-three years, the 4 that remained confined to the radial bursa averaged thirty-seven and a half years of age In an even larger series my findings have been similar It cannot be emphasized too strongly that in the early stage of secondary involvement of the ulnar bursa there is no marked swelling upon the palmar surface and that there is no special tumefaction over the ulnar bursa

One fact may confuse the surgeon in that the tenderness over the radial bursa may be absent Not only that, but upon operation no macroscopic pus may be found in the middle part of the sheath By careful extension of the incision and pressure upon the two ends pus may be brought into the wound

The extension of the infection into the radial bursa is generally accompanied by a swelling above the transverse carpal ligament, just as in ulnar bursa infection It may rupture from here into the major forearm space, and then the pus lies under the flexor profundus tendons as previously described in discussing rupture of the ulnar bursa (See Chapter V and subsequent pages in this chapter for complete discussion of forearm extensions)

The diagnosis of involvement of the wrist-joint will be discussed in Chapter XXVI

THE SYMPTOMS, SIGNS AND DIAGNOSIS OF MAJOR FASCIAL-SPACE ABSCESSES

The well-defined spaces I have described as being present in the hand may be infected primarily, or secondary to a tendon-sheath infection In either case the symptoms and signs are the same except that the diagnosis of the location of the pus is simplified when we have had a given finger sheath involved, as has already been pointed out Let us discuss the question, however, as if we were dealing with one or more of the spaces with-

out relation to tenosynovitis The student will have no difficulty in combining or differentiating the two pictures if they are present in an individual case, and the differentiation must be made, since in draining a tendon sheath we do not drain a fascial space, nor *vice versa.* Each must be treated separately, even if in a given case the two infections are combined

The symptoms and signs may be divided into local and general The general evidences of this variety of infection do not differ at all from those seen elsewhere The temperature often reaches 103° to 104° F, and the restless tossing of the patient, the sleepless nights, the wandering eye, the sweaty brow, and the flushed cheek all demonstrate the absorption of the toxins, bound in closed spaces, with no means of exit

Locally, one elicits *tenderness limited to the area involved* This localization of the pain is not so definite, however, as that noted in the synovial-sheath infection, particularly not in those patients in whom the mental equilibrium is disturbed as a result of suffering and septic intoxication After a number of days the tenderness and pain grow less severe, owing to the edema with pressure on the nerves Unfortunately, the brawny induration so helpful in diagnosticating subcutaneous accumulations of pus cannot be definitely elicited upon the palmar surface, owing to the palmar fascia and its general rigidity. Upon the dorsal surface, however, the induration and localized tenderness will aid us materially in distinguishing between the doughy, pitting edema which is always present and an accumulation of pus, long before fluctuation gives its tardy evidence The position of the fingers is worth noting. Incident to any inflammatory process about the palm of the hand, with its consequent edema, the fingers tend to become flexed, here, however, the flexion of the fingers is neither so marked nor so rigid as in synovial-sheath infection.

The Middle Palmar and Thenar Spaces.

If the middle palmar space be involved, we are often aided in making the diagnosis by the site of the primary injury. Since in the chapter upon Pathogenesis (Chapter XIX) the routes of extension from various fingers and parts of the hand were pointed out, it is not necessary to go into detail upon this subject again, although an example may be given For instance, in Case XV the palmar space was evidently involved The fistulous tract on the dorsum opened over the metacarpal bone of the hypothenar area dorsally, but with the facts in mind that the metacarpal bone of the middle finger was fractured and infected, and also that pus in the subaponeurotic space would tend to point at the side, a diagnosis of pus in the middle palmar space rather than the hypothenar was made Drainage of this space was instituted, and the immediate fall of the temperature, with rapid convalescence, substantiated the diagnosis Tenderness most marked over this area, swelling of the whole hand, marked upon the ulnar side (or it is better to say without the excessive swelling of the thenar area which characterizes infection of that space), aid us in making the differential diagnosis The obliteration of the concavity of the palm and the presence of a slight bulging is almost pathognomonic, since while edema may produce an obliteration of the concavity, I have never seen it produce a bulging or convexity—a condition which I have seen in all large abscesses of the middle palmar space Attention is drawn to the relative swelling of the thenar and palmar areas, since in palmar infections the swellings of the two might be almost the same, owing to the rigidity of the palmar fascia over the one and its absence over the other, the swelling of the thenar space being due to associated edema On the contrary, however, infection of the thenar area is characterized by a much greater swelling in the thenar than the more resistant palmar tissue, and,

moreover, the swelling of the thenar region is greater than that due to the collateral edema of mid-palmar infection (Fig. 137)

The position of the fingers does not aid much, though we expect the middle, ring, and little fingers to be held in their characteristic positions more markedly than the index when the middle palmar space is involved, while the converse is true in thenar-space involvement It is

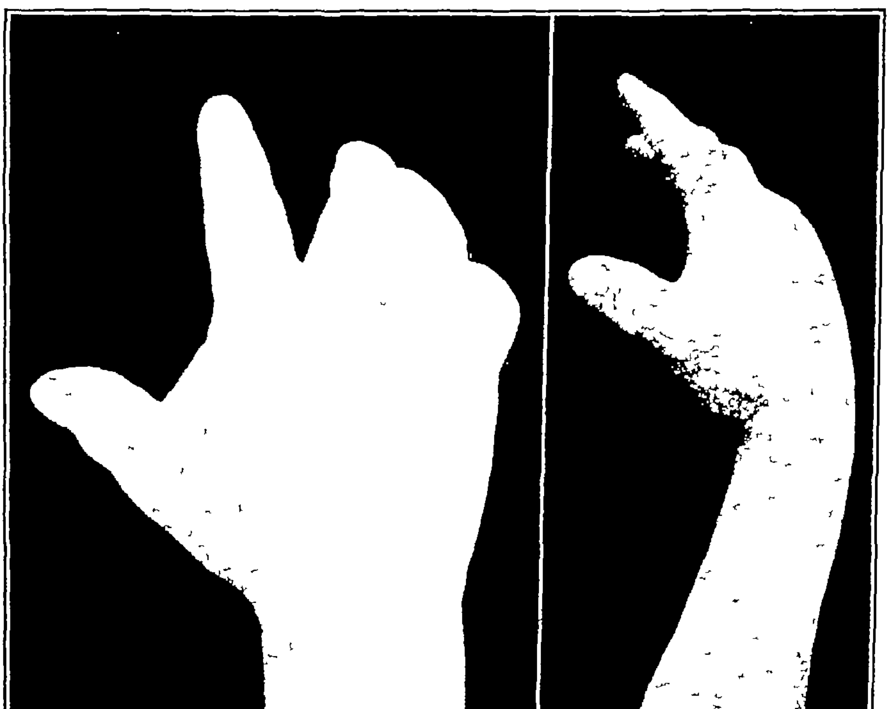


FIG 137 —Photograph of hand with pus in the thenar space Note ballooning of the thenar area

well to remember that the fingers can be moved from their positions with much less pain than is elicited when the fingers are involved in a tenosynovitis.

The great difficulty in making the diagnosis, however, is not in those cases in which the question is only which space is involved; it is when we ask ourselves, Are they both involved? or when we wish to know whether a mid-palmar-space infection has spread over into the thenar space, or *vice versa*. Fortunately, however, the thenar-

space infection does have, to a certain extent, that induration which has been spoken of as being absent in infections under the palmar fascia, and this aids us, slightly at least, to differentiate between collateral edema and pus in this space Moreover, the history helps us some. Given a primary palmar-space infection for several days, we note a rapid increase of the size of the thenar area, the edema upon the dorsum, which has not been so great as that upon the ulnar side of the hand, becomes greater, the palmar surface swelling becomes very marked, the tissues of the thenar area seeming to balloon out, as it were, from the adduction crease of the thumb, the thumb metacarpal is pushed away as far as possible from the hand, and the flexion of the distal phalanx becomes more marked, although lacking the rigidity of synovial infection of the flexor pollicis longus In such a case we now fear an extension into that space

The extension of an infection from the thenar to the palmar space is not so common, fortunately, since diagnosis is made earlier and the proper treatment instituted

The immense size to which these infected hands may grow can hardly be believed unless they are seen I recall particularly a patient who presented himself with such a hand which had been treated for four weeks without the surgeon having diagnosticated and opened a typical middle palmar abscess It is that of the patient whose hands are shown in Figs 138 and 139 (Case XIX). In the photographs the two hands are upon the same level, and the size of the infected hand is not exaggerated in the picture It could be compared to nothing except the appearance of a large turtle The patient had had ten to fifteen incisions upon the fingers and dorsum of the hand when I saw him Only one incision, that of the middle palmar space, was necessary for drainage A cupful of pus was evacuated, and the patient ultimately recovered

complete function of his hand, as will be seen by examining Fig 140. He had been advised by several surgeons to have his hand amputated. There might be some excuse for the failure to diagnosticate the position of pus, since the long-continued infection had so obtunded the nerves



FIG 138 —Photograph of dorsum of infected hand in which the pus was in the palm (See Case XIX) Note the multiple unnecessary incisions upon the dorsum.

that he complained of no pain or tenderness This is only one of the several patients that have been seen some weeks after the beginning of the infection in which the diagnosis as to the position of pus has not been made, and in consequence of the apparently desperate condition of the hand the advice to amputate had been given, and

yet upon proper drainage the patients secured serviceable hands. (See Case XXIV)



FIG 139 —Photograph of palmar surface of the same patient Note wound leading along lumbrical muscle through which the middle palmar space was drained This is the largest hand I have ever seen The pictures show the right and left hands respectively of the same patient They are on the same level and the same distance from the camera (Case XIX)

CASE XIX —Geo S , Streator, Illinois *History in Brief* —Four weeks ago patient cut his hand on a piece of steel He was in the hospital four days, and it apparently recovered Following this, numerous small pockets of pus developed upon the fingers, which were opened by a surgeon The hand began to swell enormously, and incisions were made upon the dorsum of the hand without evacuating much pus The patient began to suffer from systemic intoxication

Examination on Entrance — General condition· temperature, 101° F , pulse, 120, respirations, 26 Marked headache and emaciation, general evidence of systemic intoxication Locally, left hand swollen to two and a half times normal size The fingers are from 1 to 1½ inches in diameter. The hand is at least 3 inches thick, swollen both upon the flexor and extensor surfaces Forearm slightly swollen. Numerous incisions upon fingers and dorsum, from which exudes a moderate amount of pus There is little or no tenderness about the hand



FIG 140 —Result (Case XIX, Figs 138 and 139) six months after treatment Note perfect function of all fingers and all joints

Upon the bulging of the palm and the lack of evidence of tendon-sheath involvement, a diagnosis of an abscess in the middle palmar space was made Incision along ring finger lumbrical A cupful of pus was evacuated

After-history —Following the operation the temperature rose to 103° F , and fell the next day to 99 8° F It rose to 102° the second day, and then fell to 99 4° F , from which times it gradually reached normal The swelling slowly subsided under hot baths and active and passive movements, so that the patient left the hospital at the end of five weeks, with three-fourths function in the hand, and at the

end of four months, when I had an opportunity to examine the patient, the function was perfect in every respect, as will be seen by examining the photographs (Figs 138, 139 and 140)

Infrequently we see uncomplicated necrosis of the palmar fascia The source is commonly a punctured wound of the palm followed by infection The concavity of the palm is lost, but there is less limitation of motion of the fingers than is seen in palmar-space and tendon-sheath infection The process is less acute than that commonly seen in ulnar bursitis While the differentiation from middle palmar infections is more difficult a mistake in diagnosis is not of serious consequence since at operation the condition is recognized

The Hypothenar Space

Involvement of the hypothenar space can often be prognosticated from the site of the primary injury, while the relative lack of swelling in the palm and fingers, with absence of involvement of the tendons, combined with ordinary symptoms of abscess, lead us to an easy diagnosis Fortunately, the hypothenar area is so separated from the remainder of the hand that it is seldom if ever involved secondary to palmar infection

Dorsal Abscesses

Attention is called particularly to the rarity of abscesses upon the dorsum This is necessary since the unthinking surgeon so commonly makes incisions upon the dorsum in patients having infections of the hands The excessive swelling due to edema is mistaken for pus The diagnosis of pus here is easily made and *no incision should be made except in the presence of definite findings*

The excessive edema upon the dorsum is due to the fact that there we have a large area of loose subcutaneous tissue in which serum can accumulate, and secondly, to the anatomical distribution of the superficial lymphatics,

which, as we have pointed out, all seek the shortest course from the palmar surface to the dorsum Consequently, one often finds much greater swelling upon the latter than the former, even though the abscess be upon the palm. If, however, we bear in mind the soft pitting of edema, with its generalized moderate tenderness, as opposed to the induration with slight pitting and localized tenderness of the abscess in this tissue, the diagnosis is easy One should never wait for fluctuation to make a diagnosis of abscess formation, it should be made from the induration.

An infection localized under the subaponeurotic fascia to the exclusion of the subcutaneous tissue may be difficult of differential diagnosis. However, we are aided materially if we remember the character of the primary injury, the methods of extension to this space already mentioned, and the local evidences of infection upon the dorsum, with the pitting edema of the subcutaneous tissue, yet lacking the brawny induration and localized tenderness of a subcutaneous abscess.

FOREARM INVOLVEMENT FROM INFECTIONS OF THE HAND.

Pathology and Diagnosis

Forearm involvement occurs in two forms—that associated with lymphangitis and that following tendon-sheath infection of the flexor tendons and abscesses in the palm. The pathology and localization is essentially different, as it arises from the two sources. I refer, of course, to suppurative involvement, and have no reference to the edema which always occurs with any infection

SUBCUTANEOUS ABSCESSES

Abscesses following lymphatic infections have been considered in detail in the chapters devoted to that subject. Let me repeat that we may have a secondary

involvement upon both the flexor and extensor surfaces. Upon the flexor surface we find a localization just above the transverse carpal ligament in many cases of deep infection of the hands, particularly those cases showing an ulnar bursitis This is characterized by redness and slight induration over an area 2 or 3 inches in length at the lower end of the forearm The diagnosis is not difficult, the only thing to be borne in mind being that the surgeon should understand its origin and should not desist from dealing with the extension under the tendons from a rupture of the synovial sheath, since there is no connection between these foci, and draining the superficial pocket does not drain the deeper and more important focus

Besides this well-differentiated localization, small foci may develop along the lines of any lymphatic, either on the flexor or dorsal surface Care should be taken not to mistake these uncommon localizations for the acute non-suppurative inflammation of the lacunæ Again, localizations may take place about the glands of the epitrochlear region, as has been described in Chapter XVI

The most important subcutaneous accumulation associated with lymphatic infection occurs upon the dorsum of the forearm This condition, characterized by a brawny induration of the entire dorsum, with necrosis and sloughing of the subcutaneous tissue, is one of the gravest complications met with in hand infections. A full discussion may be found in Chapter XIV.

DEEP ABSCESSES

The deep involvement, no matter what the origin, almost always is found upon the flexor surface. This most commonly arises through extension by rupture of the proximal end of the ulnar or radial bursæ In either case the pus occupies the major forearm space

which, as we have pointed out, all seek the shortest course from the palmar surface to the dorsum Consequently, one often finds much greater swelling upon the latter than the former, even though the abscess be upon the palm. If, however, we bear in mind the soft pitting of edema, with its generalized moderate tenderness, as opposed to the induration with slight pitting and localized tenderness of the abscess in this tissue, the diagnosis is easy One should never wait for fluctuation to make a diagnosis of abscess formation, it should be made from the induration.

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in the forearm These experimental and anatomical deductions were verified by a study of all my cases showing this complication, as well as an extensive review of cases reported in the literature The result was beyond expectation The study enables the surgeon to prognosticate before operation the exact location of pus in the forearm It suggested new sites for drainage which cured patients in from one to two weeks by two, or at most three, primary incisions, who by the older procedures would have required from three to five weeks, with the probability of many complications

The anatomical and experimental work I have detailed in Chapter V It remains for me, therefore, to adduce the clinical proof of its correctness and suggest plans of treatment It will be seen, by referring to Chapter V, that the final deduction made from the researches was that the important space in which pus would be found in those cases where the infection originated in the hand had the following boundaries. It lies under the flexor profundus digitorum tendons and muscle About 3 inches up on the forearm the pus begins to invade the intermuscular septa, passing first to the area about the median nerve and later to the area about the ulnar artery and nerve Here it lies between the flexor carpi ulnaris and the flexor profundus This is about 4 inches up on the forearm From here it may pass toward the elbow along the vessels and nerves, particularly the median nerve, or more commonly it may extend distally along the ulnar artery under the flexor carpi ulnaris and appear subcutaneously about 3 inches up on the ulnar side. It may extend downward along the radial artery, but this is certainly an uncommon termination The largest part of the space is about 2 inches above the wrist Its most superficial parts are on either side just volar to the ulna and radius The floor of the space is made up by the pronator quadratus at the wrist and

LOCATION OF THE ABSCESSES.—It has been the custom of surgeons and writers dealing with this subject to speak of these abscesses in a general way only, and to suggest drainage through the volar surface between the tendons and muscles In my earlier patients I was struck with the long convalescence, the repeated incisions, and the inade-

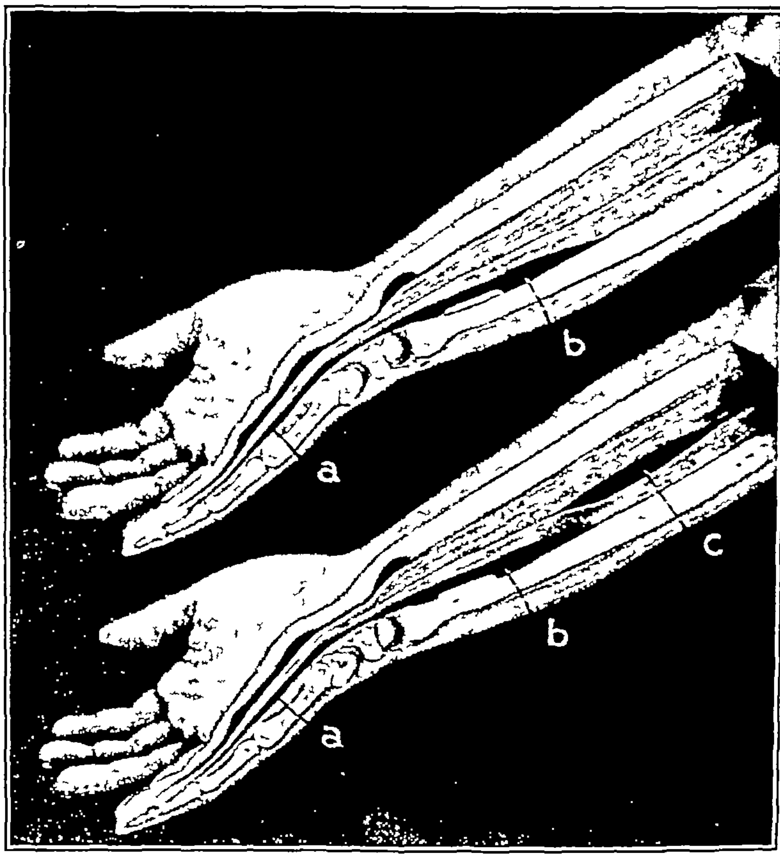


FIG 141 —Extension of pus from the ulnar bursa into the forearm *a*, ulnar bursa, *b*, extension into the major forearm space, *c*, intermuscular pus pocket in upper forearm

quate drainage owing to the rapid closure of the sinuses through the muscular bodies Therefore a careful study of the anatomy of the forearm was undertaken, both by dissection of serial sections and by experimental injections made through the various tendon sheaths and from other sites of predilection of pus in the hand By this I determined the probable site of these secondary abscesses

forty-eight to seventy-two hours extension to the space may be assumed In any case, we have the development of increased swelling of the forearm. The swollen part has not the soft feeling incident to edema, but a full, tense feeling as if the forearm were an overdistended bag There may be but little increase in redness The induration seen in subcutaneous abscesses will be absent However, tenderness to deep pressure is increased The

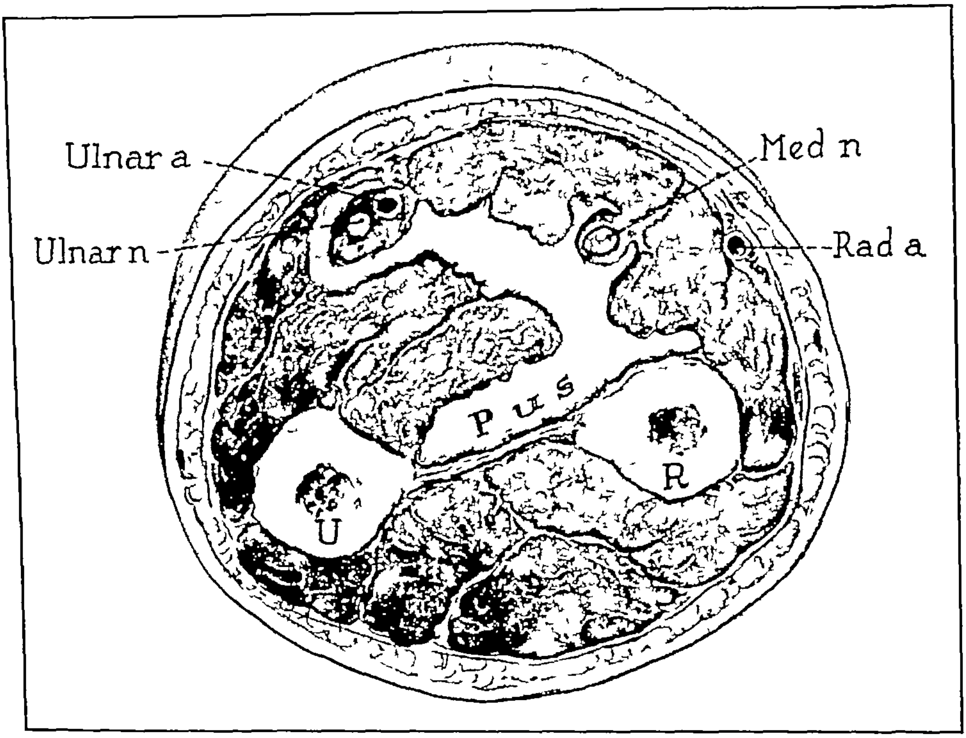


FIG 143 —Photograph of forearm just below the middle, showing position of pus (white area) in its relation to the ulnar artery and nerve and the median nerve

wrist becomes more or less fixed, and the careful observer has no difficulty in suggesting the diagnosis on the history of these findings Of course, later, when the pus has infiltrated every part, even the novice can make the diagnosis Early diagnosis is greatly to be desired, however It should be urged that in case of doubt incision may be made after the manner suggested, by lateral incision, without in any way jeopardizing the patient's

the interosseous septum above. The space may hold a half pint or more of fluid. This space I have named the *major forearm space* No other well-defined space is present except that comprising the subcutaneous tissue

Every case that has come under my observation has borne out these deductions and from these cases and my studies it is certainly justifiable to outline the position of these secondary abscesses as we have The

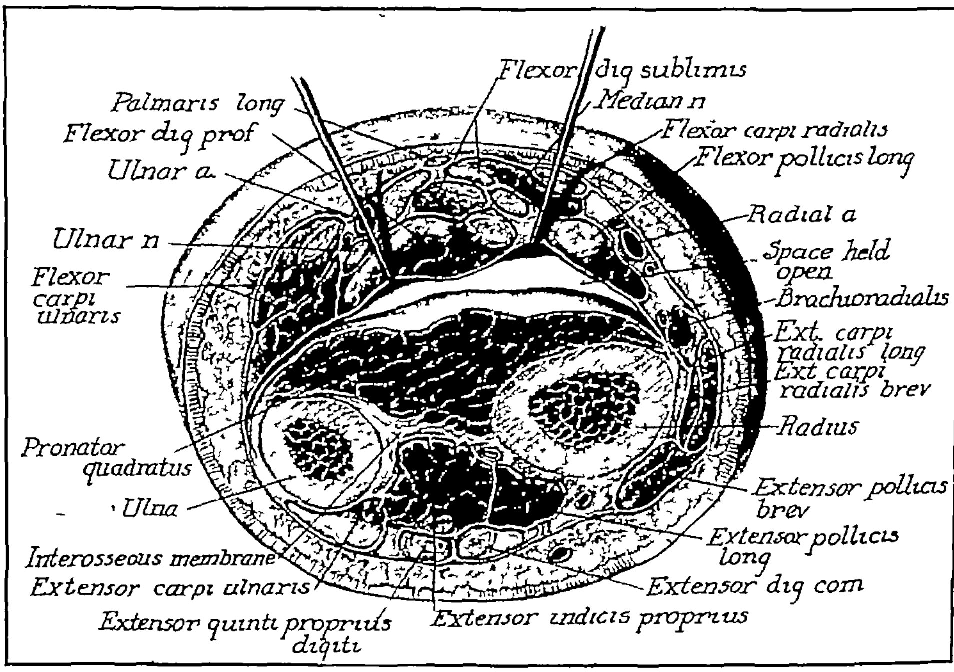


FIG 142 —Cross-section 7 cm above the radial styloid The open space is the major forearm space in which the pus is found in extensions from the bursæ in the hand

position of the pus at a point 1½ inches up on the forearm is shown in cross-section (Fig 142), and also the position of the pus when it reaches the middle of the arm is shown in a second cross-section (Fig 143)

SYMPTOMS, SIGNS, AND DIAGNOSIS —The diagnosis of a forearm involvement is based on the knowledge of an associated tendon-sheath infection of the ulnar or radial bursæ and the signs incident to the development of any deep abscess In any ulnar or radial bursitis lasting

proximal interphalangeal joint of a finger or a gonorrheal tenosynovitis with secondary involvement of that joint The latter assumption was later found to be the condition present. In those cases where there is a lack of traumatic history and an apparently spontaneous development of an inflammation, especially at the wrist, the diagnosis between arthritis and tenosynovitis may be most difficult in spite of the ease with which a theoretical differential diagnosis is made. Here, again, however, the localized tenderness over the sheath and pain on extension of the finger are of the greatest importance, moreover, these cases are always virulent and extend rapidly, so that if it be a tenosynovitis, the hand grows rapidly worse In a rheumatism there is as much pain on the dorsal as on the volar surface, the swelling involves the wrist more than the hand, fingers, or forearm, and other joints may be involved The presence of a gonorrhea does not aid us materially, since either condition may follow One case of gonorrheal tenosynovitis of the tendon sheaths of the dorsum of the wrist came under my notice in which the diagnosis of rheumatism had been made Here the absence of any tenderness or swelling on the flexor surface combined with swelling and tenderness localized to the sheaths confirmed the diagnosis Subcutaneous infections are seldom difficult to differentiate

forearm Whenever I open an ulnar or radial bursa, and there is any question in my mind as to forearm involvement, the ulnar forearm incision is made Indeed, this same incision may be used to drain the upper end of the sheaths in the forearm So that the incision thus serves two purposes it drains the bursæ, and makes certain our diagnosis

Osteomyelitis, arthritis, and secondary hemorrhage from the ulnar artery will be discussed in the chapter dealing with the complications of infections

Tendon-sheath Infection on the Dorsum of the Wrist

In the following case there was a neglected tendon-sheath infection on the dorsum These cases are extremely uncommon, since they are generally only local abscesses without extension

Case XX —An infection extended upon the back of the forearm, after two superficial abscesses had been opened, it was noted some days later that there was a painful swelling on the dorsal ulnar side of the forearm, this was incised as far as the fascia without freeing any pus A pocket was found, however, under the dorsal carpal ligament extending into the otherwise healthy muscle above

Differential Diagnosis

One may mistake a lymphatic infection for a tenosynovitis Here, however, the red lines of lymphatic involvement running up the arm without localized tenderness over the tendon sheaths, the slight pain on moving the fingers, the generalized edema of hand and arm in contradistinction to the localized swelling found in the early stage of tenosynovitis aid us in the diagnosis. Again, we may be in doubt as to whether we are dealing with a tenosynovitis of the ulnar or radial bursa, or a rheumatism of the wrist I have seen several such cases. In one case it was difficult to determine whether the patient was suffering from a gonorrheal rheumatism of the

form of voluminous moist, hot dressing   Boric acid solution in saturated strength is most commonly used, but any of the other solutions in common use are probably just as efficient   Carbolic acid dressing in any form should be avoided because of the danger of gangrene   Local painting with ichthyol, iodine, and such irritating solutions is absolutely useless   German surgeons speak highly of 95 per cent alcohol dressings left on twenty-four hours   They probably are no more efficient than the hot boric solution and are always a source of some anxiety, owing to the possible danger of their catching fire, as occurred in one instance that came to my attention   Probably the next most essential procedure is to keep the part at rest, this, of course, is indicated in any infection, since the muscular action tends to disseminate the germs, thus extending the area to be walled off by the leukocytes   Elevation of the parts is recommended by many, but personally I could never see any advantage in it except to make the arm comfortable, and it is true the elevation of the hand is sometimes necessary for this   If the infection is severe, put the patient in bed   Keep the bowels open and the kidneys active   Preserve the nutrition of the patient

TECHNIQUE OF TREATMENT AFTER DIAGNOSIS IS MADE.

The diversity of opinions as to the proper methods of treatment held by various surgeons, is sufficient proof of the severity of this condition and the difficulty of its treatment   It emphasizes the frequency of bad functional results and should stimulate us to most careful study of our cases.

The diagnostic acumen of the operator cannot but be a vital factor in the treatment. It is probable that too many will err on the side of conservatism in the treatment of the first cases of tenosynovitis that are met   It will be

CHAPTER XXIII

THE TREATMENT OF ACUTE SUPPURATIVE TENOSYNOVITIS—DISCUSSION OF TECHNIQUE.

FOLLOWING the anatomical investigations detailed in the previous chapters and a careful study of all clinical cases coming under observation, certain procedures were instituted, which in my hands have given most satisfactory results The chapter upon the "General Principles of Treatment" should be consulted for a consideration of the various general procedures mentioned They are not here discussed in detail since they are applicable to all cases The technique which I have used in these serious cases is herewith described This may be classified under three heads

1 In the early hours while the diagnosis may be in doubt
2 When the symptoms and signs of tenosynovitis are marked
3 After-treatment

TREATMENT WHILE THE DIAGNOSIS MAY BE IN DOUBT

While at times, when a finger is infected, it is some days before the tendon sheath becomes involved, it is often early, and when it is invaded the symptoms develop rapidly because, as was mentioned above, there is so little resistance that the infection spreads throughout the sheath in a short time However, during the preliminary stage, much may be done to prevent a spread into the sheath The best sort of application is undoubtedly some

anesthesia and in a bloodless field Where possible, the gas-oxygen anesthesia is to be preferred to ether Where the process is especially virulent and acute, I leave on the Martin bandage for twelve to eighteen hours after the operation Care is taken, however, to loosen it so as to produce only a passive hyperemia In other words, a Bier's hyperemia is secured for this time This is done not so much for the therapeutic effect as to prevent the rapid absorption of virulent toxins It is hoped in this manner to give the patient time to react and develop antitoxins to overcome the poison rather than allow him to be overwhelmed by a large amount of virulent toxin absorbed at one time

Treatment of Tenosynovitis of the Index, Middle, and Ring Fingers

Extreme care should be taken to preserve an aseptic technic both at operation and in the subsequent dressings, since the infection of the synovial sheaths is most often due to the streptococcus If the operation has been instituted before destruction of the synovial covering, recovery will be prompt with good function preserved If, however, a secondary staphylococcic infection is superimposed, treatment is prolonged and great impairment of function ensues Garlock has emphasized this in a very excellent contribution to the subject

The procedure will vary according to the type of infection and the amount of destruction present The first incision is made at the site of known infection, opening the sheath at the side and not in the median line, cutting the length of the sheath on the proximal or middle phalanx, and leaving the part over the articulation uncut so that the tendon does not prolapse, unless there is doubt as to the freedom of drainage After having opened the sheath at the infected point, pressure upon its various parts will give one some idea of the extent of the invasion.

reasoned that since some damage already will have occurred to the tendons, if they are involved, a few hours' delay will not add seriously to the condition. This possibility will be preferred to that of opening and infecting an uninvolved sheath. However, these few hours are of great importance in the fulminating type, and operation should be most prompt.

I do not intend this as advocacy of operation regardless of accurate diagnosis, but as a stimulus to careful study to the end that the surgeon, being better qualified, may neither, by ill-advised conservatism, delay necessary operation, nor by thoughtless, audacious incisions jeopardize the usefulness of a healthy hand.

My own opinions as to the best methods are based upon my anatomical researches and upon observation of the patients presenting themselves at the dispensary and hospital of the Post-Graduate Medical School and Hospital, at Wesley Memorial Hospital, and the Northwestern University Medical School. To Professors Besley, Richter and Koch, and others of my friends at these hospitals and at the Cook County Hospital, I wish to acknowledge my appreciation of the opportunity for the study of their cases in addition to my own. Concerning the technique of treatment, undoubtedly the future has much in store for us that we cannot know at the present time. The subject is one not only of local condition, but of the resistance of the individual and his reaction to various toxins. In other words, the newer problems in serum pathology must first be worked out before we can attain the best results. I cannot but feel, however, that even the local conditions are not so well understood by the average surgeon as is possible, and that our bad results would be reduced at least by one-half if more study were given to careful diagnosis.

I have secured the best results by the following procedures: *Operation should always be done under general*

If, however, there is some question whether the lumbrical spaces at the sides have begun to become involved, the incision is made upon the side most affected, opening the space and the tendon sheath at the same time If both sides are involved, two incisions are made The finger is now cleansed and examined If infection is present the incision is carried up on the side of the finger as described, thus making *one incision the length of the sheath or as far as necessary to secure adequate drainage*

I have tried cutting down to the sac in doubtful cases, then inserting an aspirating needle and attempting to drawn off some pus for diagnostic purposes, hoping by this procedure to avoid the possibility of infecting an uninvolved sheath through opening it with a scalpel While, theoretically, the procedure would appear to be advisable, practically it is of little aid The bulging of the sheath, proving the presence of fluid under tension, is generally easily seen, while a failure to secure pus by aspiration is not sufficient evidence of its absence

When the Involvement of Adjacent Areas Has Begun —The involvement of the articulation between the middle and proximal phalanges, which occurs in late cases, will be discussed in the chapter dealing with complications and sequelæ (Chapter XXVI). The method of treatment will be outlined there I shall only add to what I have already said, that if early incision of the sheath is made this involvement is generally prevented. another reason for early incision. As has been pointed out, the paths of extension in the involvement of the lumbrical spaces vary in the individual fingers

The Index Finger —When the infection passes to the lumbrical space on the outer side, it may extend into the thenar space, and the incision which opens the lumbrical space may be extended. Pressure upon the thenar area will force pus out along the line of incision. This is then extended along the radial side of the metacarpal bone,

If it is complete, as is generally the case, a similar incision is made over the uncut proximal or middle phalanx No incision is necessary over the distal phalanx I wish to insist that *the first requisite is adequacy of the opening for drainage*, since a small incision soon becomes closed by prolapsing tissue *Make the incision too free rather than too small* In those cases where it has seemed advisable to incise the length of the sheath, which I do

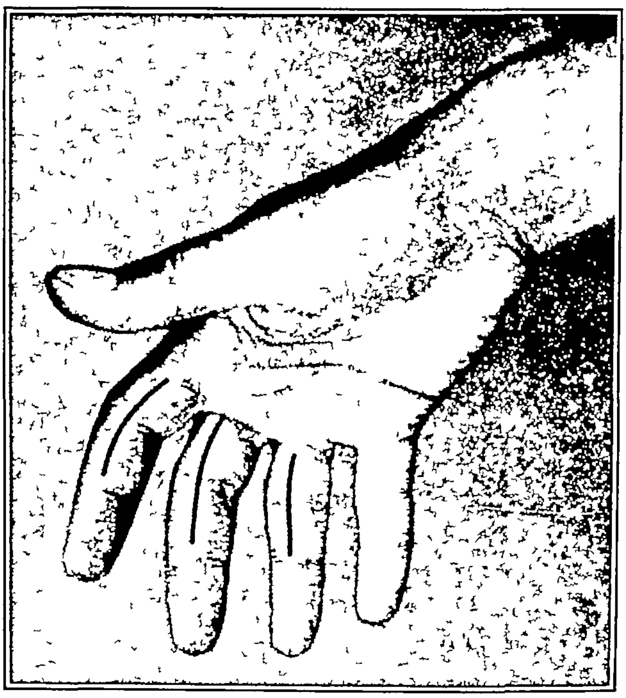


FIG 144 —Incisions for drainage of suppurative tenosynovitis of the index, middle, and ring fingers

in case of doubt, I leave the part of the tendon sheath and the vinculum uncut at the joint to prevent prolapse of the tendon In the gravest cases a complete opening of the sheath is advisable

If early and there is some question as to the diagnosis, instead of opening the sheath over the phalanx the incision is made over the middle of the sheath at its end in the palm, carrying it from the flexion crease at the base of the proximal phalanx for about ¾ inch into the palm

observed any serious impairment of function following (Fig 163).

If the infection extends proximally along the lumbrical space between the index and middle finger some care should be used in the incision, since while it generally involves the thenar it may involve the middle palmar space After the lumbrical canal is opened, pressure over these spaces will demonstrate which is involved, since pus will exude into the incision. If the thenar space is involved, after opening the lumbrical space freely

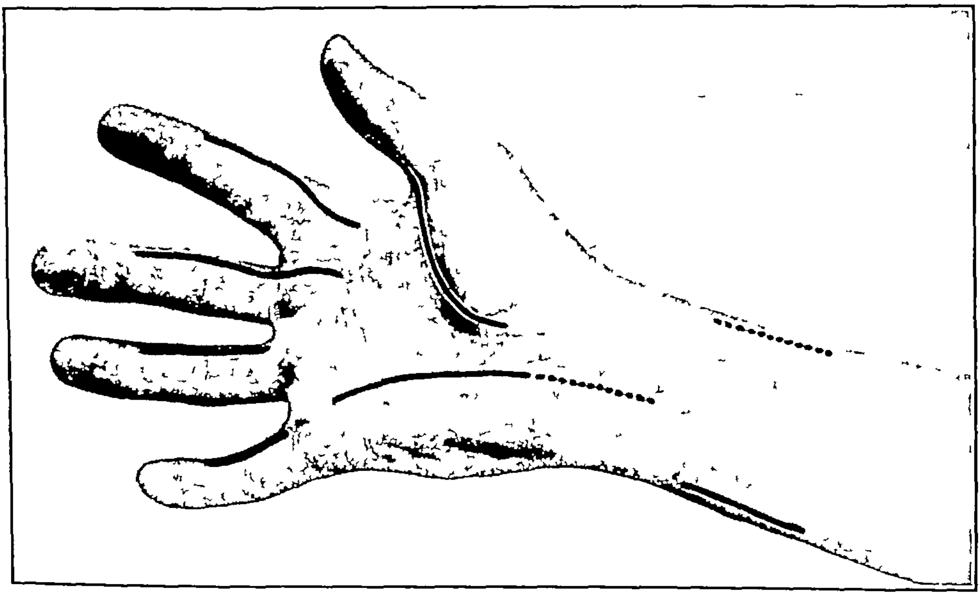


FIG 146 —Lines show possible incisions for infection of the tendon sheaths The dotted lines show incicions made in exceptional cases

the thenar space is opened by an incision upon the dorsal surface between the metacarpal bones of the thumb and index finger, *i e*, drainage of the thenar space as described above and also in Chapter XXIV In those exceptional cases in which the middle palmar space is involved the lumbrical incision is supplemented by an incision over the middle palmar space following up the lumbrical space between the middle and ring fingers as described below under "The Middle Finger" (A more extended discussion is found in Chapter XXIV)

the incision lying dorsal to the web which extends from the thumb to the base of the index finger The artery forceps is then carried across the palmar surface of metacarpal bone and the blades opened, thus draining the thenar space without an incision upon the palmar surface (Figs 145 and 167). Care should be used not to force the point of the forceps beyond the middle metacarpal bone, otherwise the middle palmar space will be entered and an extension to this space favored.

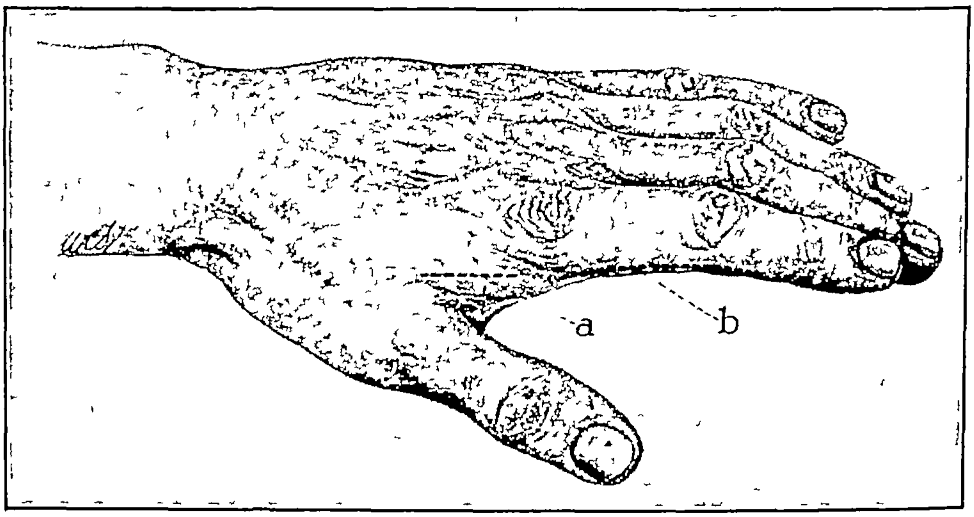


FIG 145 —Incisions for drainage of suppurative tenosynovitis of the index finger (*b*) and secondary incision (*a*) for drainage of the thenar space when pus has extended there from the index sheath

When the extension has entered the lumbrical space between the index and middle finger, the incision should be made into the sheath at its ulnar side, thus opening both the sheath and the lumbrical canal through the same skin incision If the lumbrical canal is involved, the pus may have extended distally into the loose mesh of tissue at the web or proximally If distally, it may be necessary to add a second incision upon the dorsum between the bases of the index and middle fingers, and procure through-and-through drainage of the web, or at times I have split the web completely and have not as yet

that almost always it will be found advisable to make a single incision on the lateral surface the length of the two proximal phalanges, since we wish to procure perfect drainage, and thus avoid possible extensions

When we come to the base we may have extension either into the ulnar bursa, the lumbrical space, or both In the more acute cases the former alone is most common, while in the more chronic type it is often both Here the incision opening the tendon sheath can be made to drain the lumbrical space

Extensions into the middle palmar space are opened by following along the lumbrical space as in the other fingers if the ulnar bursa is uninvolved If this latter is invaded, the same incision which opens the ulnar bursa may be utilized by inserting the forceps through the synovial wall of the bursa under the tendons into this space If the pus has extended over to the thenar space, it should be drained by making the incision upon the dorsum between the metacarpal bones of the thumb and index finger and opening it by the forceps, as was described above when discussing the extensions from the index finger

In a few of the cases there is a congenital separation of the proximal from the distal portion at approximately the metacarpo-phalangeal articulation, and in a certain proportion of these cases in which there is no separation the opening is so narrowed that there is a temporary dam produced by serous adhesions if the inflammation is not too fulminating in character, which unfortunately it generally is In the former condition there is little likelihood of a spread to the ulnar bursa, so that we should be extremely careful not to open this bursa unless we are certain that it has become infected, since we are exposing the patient to grave danger On the other hand, if the occlusion is of temporary inflammatory origin, we can see readily how important it is that an early diagnosis of the condition should be made and proper treatment of the

The Middle Finger.—When extension occurs into the lumbrical canal upon the radial side, or the web on either side, the technique of treatment is that just described When the extension is along the lumbrical canal between the middle and ring fingers toward the palm, early the pus may be between the palmar fascia and the tendon in the "loft," as already described, but it very soon involves the middle palmar space Here the incision is carried ¼ inch into the palm, *i e*, proximal to the transverse line joining the ends of the flexion creases If pus is expressed through this from the palm, an artery forceps is inserted under the tendons going to the ulnar

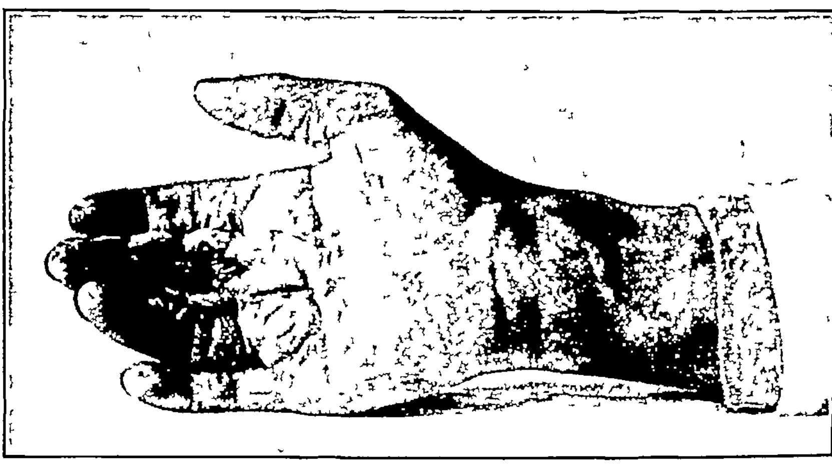


FIG 147 —Incision in the palm along the lumbrical canal for drainage of middle palmar abscess from suppurative tenosynovitis of the middle finger

side and the blades opened No drainage is inserted, although in a few instances I have placed in the pocket small strips of rubber dam Ordinary gauze acts simply as a plug, and I never use it

The Ring Finger —Here the extension to the web or into the middle palmar space from either side is treated by the same technique as described above

Treatment of Tenosynovitis of the Little Finger and Ulnar Bursa

If the finger alone is involved, the treatment is the same as that noted above for the other fingers, except

tion depends in all probability the proper solution of the question, and it will take a large number of carefully observed cases to arrive at a decision. Increasing experience, however, has confirmed me in the opinion that it is wiser to incise at a known point of involvement This pocket being opened, pressure is exerted over the sites of predilection in continuity If they are involved, pus will be seen to enter the previously opened site. A grooved director is now inserted along the canal and the incision continued or the focus opened by the proper methods

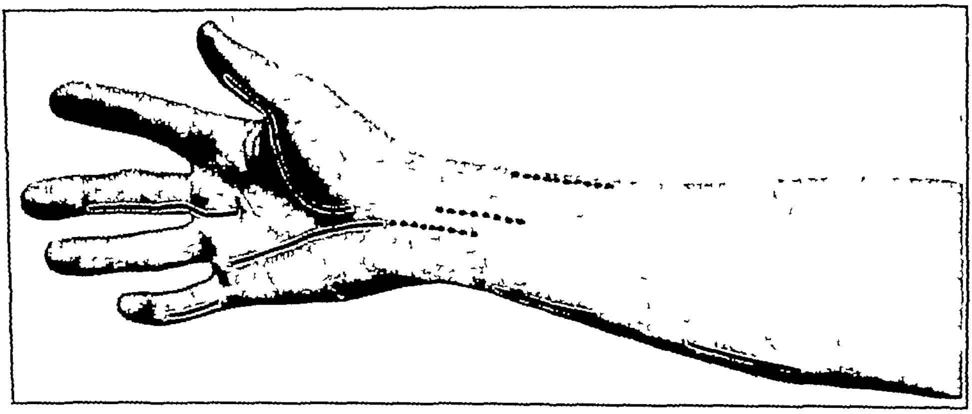


FIG 149 —Lines represent various incisions made for infections of the tendon sheaths and their possible extensions into the forearm The dotted lines represent incisions made only under exceptional circumstances (See text for complete description)

When the continuation of this sheath in the hand is involved, the palmar portion is opened by an incision extending from the distal flexion crease of the palm to the anterior annular ligament on the *radial side* of the hypothenar eminence (Fig 149). It is my custom to insert a grooved director in the opened sheath and follow along this, cutting the tissues between the sheath and the surface, having the thought in mind to avoid the tendon and cut as far to the ulnar side of the sheath as possible, since there will be better drainage, particularly at the wrist, if this is done (Fig 150). After the transverse

distal portion instituted to prevent a spread to the ulnar sheath

As to just what the proper procedure should be, in case we are fairly certain that there is an infection of the distal portion of the sheath and we are still in doubt as to whether it has extended to the proximal or palmar portion or not, there is room for discussion Forssell advises that we should begin at the point where we are least sure of infection, while Helferich suggests that we begin at the

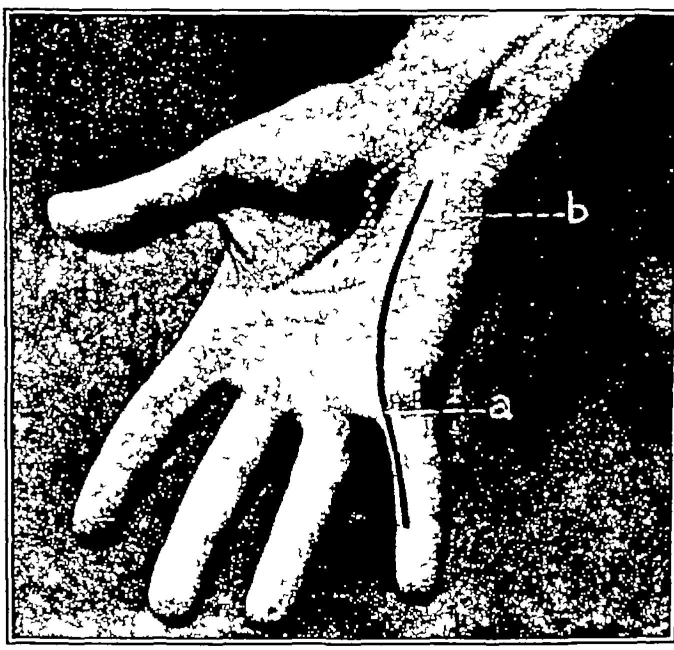


FIG 148 —Incision for suppurative tenosynovitis of the little finger and ulnar bursa *a*, incision, *b*, bursa Note that the incision lies to the *radial* side of the hypothenar eminence

point of infection where we are sure to make our way along with care Naturally we would admit the former to be the proper method if certain unknown equations did not enter into the discussion In the first place, what proportion of aseptic ulnar sheaths can be opened without infecting the sheath from the lymphatics which are constantly carrying germs from the point of infection through the subcutaneous tissue in which our so-called aseptic incision is made? Upon the answer to this ques-

ulna is incised the length of the skin incision In patients with exceptionally large abscesses here a second incision may be made upon the radial side, but this is seldom necessary. *Make the incision too long rather than too short*, since a large incision with free drainage will heal more rapidly than a small incision with inadequate drainage. Especial care should be used here to make the incision neither too far upon the flexor surface nor dorsally, since in the first instance, especially upon the radial side, the artery may be injured either by the primary incision

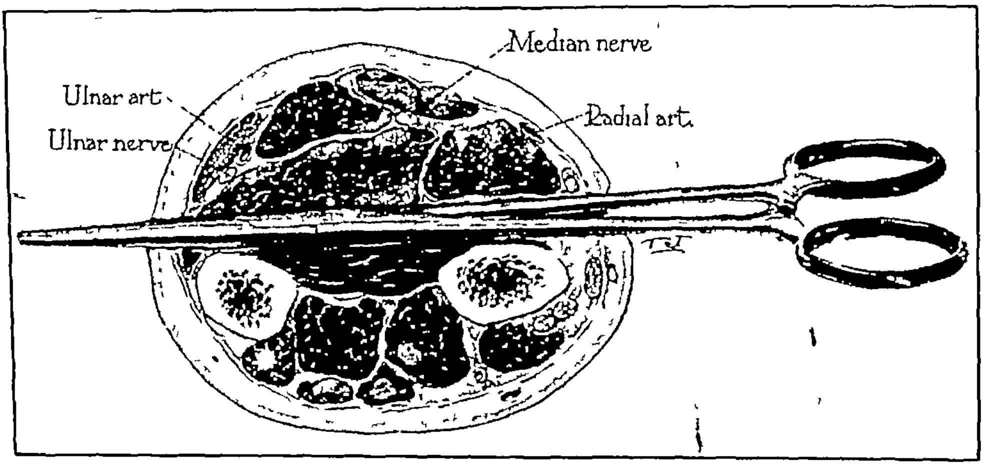


FIG 151 —Cross-section 7 cm above radial styloid Artery forceps inserted transversely in juxtaposition to ulna and radius through the major forearm space, showing that incision can be made here and not injure important vessels and nerves Notice tissue between radial artery and the forceps

or subsequent necrosis, and in the second instance, if the incision is too far dorsally, it will not drain easily. If the primary incision is made on the radial side and more distal the danger of injuring the radial artery is greater With the proper precaution, no anxiety need be felt (Fig. 151) Having opened this area, the finger is now inserted under the flexor profundus tendons, and if there is any infection of the sheath, it is bulging and can be opened easily In case it is not found easily, flexion and extension of the fingers will locate the tendons involved and the palpating finger under the tendons can open the bursa or

carpal ligament is reached, pressure above over the prolongation of the sheath in the forearm will force pus downward into the sheath below the ligament if the infection has extended here, as it generally has

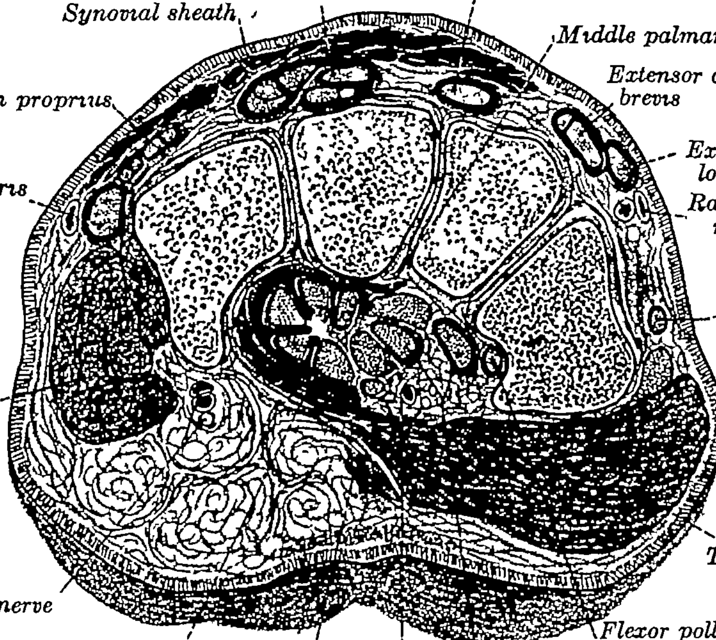


FIG 150—Cross-section No VIII The ulnar bursa, radial bursa and intermediate sheaths are shown in red

TECHNIQUE OF TREATMENT OF INFECTION OF THE PROXIMAL END OF THE BURSA IN THE FOREARM AND PUS IN THE MAJOR FOREARM SPACE.

If an involvement of the prolongation of the sheaths above the transverse carpal ligament or a forearm involvement is diagnosticated, I proceed as follows At a point about 1½ inches above the tip of the ulna an incision about 3 inches long is made directly down on this bone at its flexor surface, an artery forceps is now thrust across the flexor surface of this bone into the space under the flexor tendons. The fascial attachment of the muscle to the

ulna is incised the length of the skin incision In patients with exceptionally large abscesses here a second incision may be made upon the radial side, but this is seldom necessary. *Make the incision too long rather than too short,* since a large incision with free drainage will heal more rapidly than a small incision with inadequate drainage Especial care should be used here to make the incision neither too far upon the flexor surface nor dorsally, since in the first instance, especially upon the radial side, the artery may be injured either by the primary incision

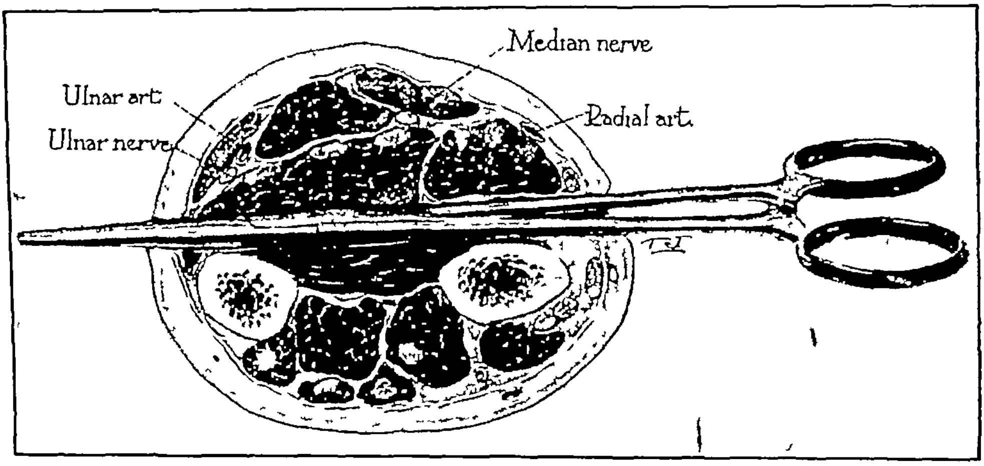


FIG 151 —Cross-section 7 cm above radial styloid Artery forceps inserted transversely in juxtaposition to ulna and radius through the major forearm space, showing that incision can be made here and not injure important vessels and nerves Notice tissue between radial artery and the forceps

or subsequent necrosis; and in the second instance, if the incision is too far dorsally, it will not drain easily. If the primary incision is made on the radial side and more distal the danger of injuring the radial artery is greater. With the proper precaution, no anxiety need be felt (Fig 151) Having opened this area, the finger is now inserted under the flexor profundus tendons, and if there is any infection of the sheath, it is bulging and can be opened easily In case it is not found easily, flexion and extension of the fingers will locate the tendons involved and the palpating finger under the tendons can open the bursa or

a forceps can be used In case there is difficulty in locating the bursa an artery forceps can be pushed along the sheath under the annular ligament from the incision in the palm (Fig 152) Its point is felt plainly by the finger under the tendons, since the bursa extends upward on the tendons

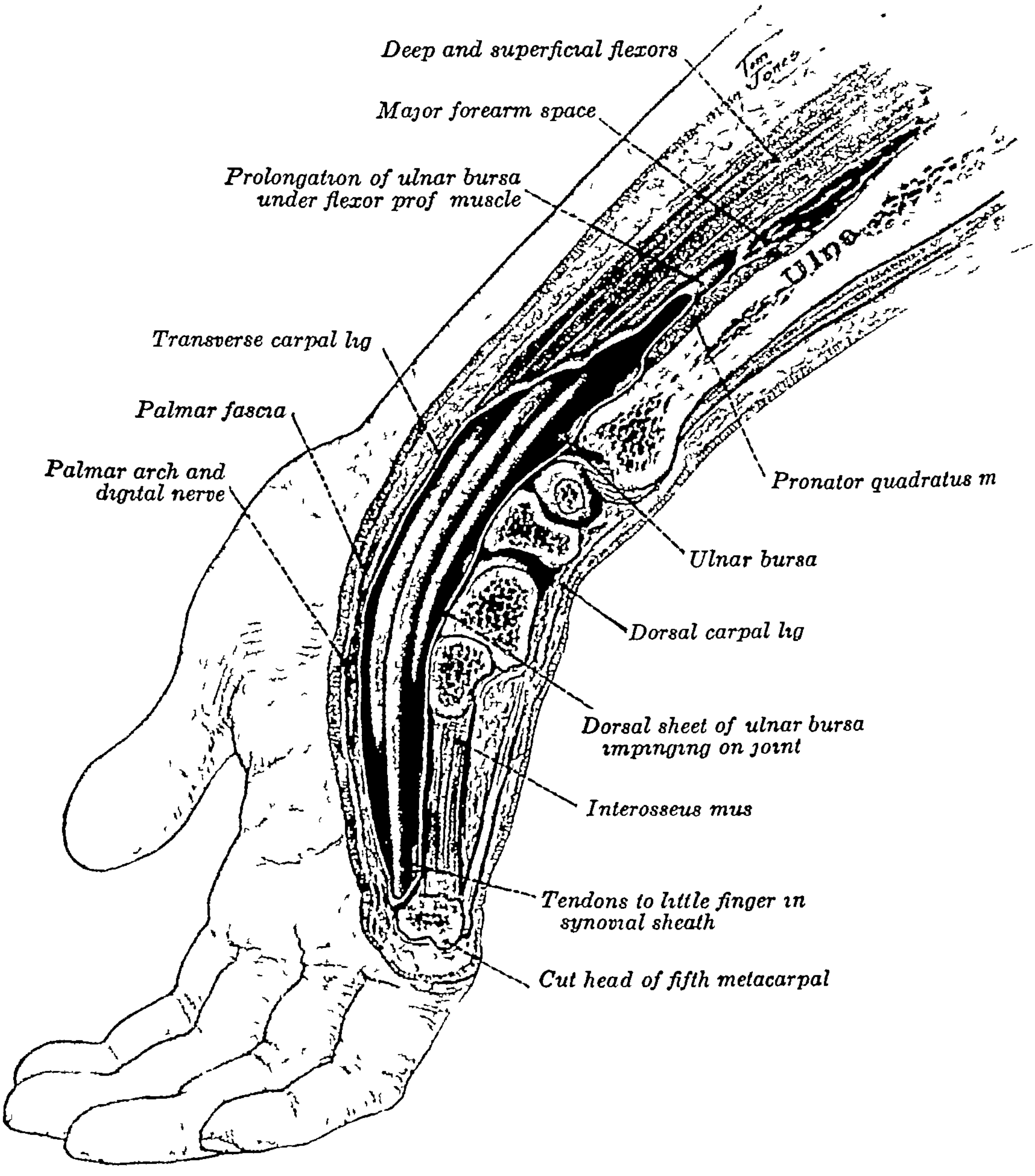


FIG 152 —Drawing showing extension of the ulnar bursa underneath dorsal surface of the flexor tendons and the major forearm space into which pus ruptures into forearm

on their posterior surface As a matter of fact, the infection will be found to have ruptured into the major forearm space in practically every case, except in the very earliest stages. *I wish to emphasize that it is upon the ulnar incision that I depend for drainage of the upper end of the bursa* (Fig 152) In other words, this site is used for entering and draining the sheath before rupture, as well as for incision for draining the extension into the forearm It will be remembered that attention has already been drawn to the fact that when extension takes place this area between the flexor profundus tendons and the interosseous septum and the pronator quadratus is always first involved (the major forearm space). In the early stages of rupture, after having cut through the skin and subcutaneous tissue, the operator will be inclined to desist, since no evidence of pus will be found. It is not until the area under the profundus is reached that one finds the pus Again, a second fallacious reason for stopping the incision at this stage may be found There may be a subcutaneous accumulation of pus on the flexor surface of the wrist, in all probability of lymphatic origin, this having been opened, the operator feels that he has drained a pocket in direct communication with the tendon sheath or may fear that his diagnosis of tendon-sheath infection has been incorrect

In those cases where there is an involvement of the major forearm space, with extension higher up along the intermuscular septa, other incisions should be added to the ulnar forearm incision just described In such cases it is always advisable to make a second incision midway between the wrist and elbow on the ulnar and flexor side of the forearm about 1 inch from the ulna. It is our desire to reach the intermuscular area between the muscular body of the flexor carpi ulnaris and the ulnar border of the flexor digitorum sublimis The incision should be 3 or 4 inches in length so as to give adequate

above the transverse carpal ligament, since the sheath lies to the ulnar side and posterior to the tendons If infected, it should be freely opened, since the swelling due to edema and inflammatory infiltration tends to close a small opening If the infection is now seen to be at all severe, the transverse carpal ligament is split as far to the ulnar side as possible The hook of the hamate interferes somewhat with the incision If it is determined when the palmar part is first incised that the transverse carpal ligament shall be cut, one proceeds differently. The incision is continued from below upward, carrying the incision about 1 inch up on the forearm This latter is made as much to drain the subcutaneous area above the wrist, which commonly becomes infected, as to open the sheath This method of drainage of the upper part of the forearm was used in my early cases before I began to use the lateral drainage under the tendons, but it in no way compares with the lateral drainage in ordinary cases *Its use should be restricted to exceptional cases.*



FIG 155 —Photograph of a hand of a patient, showing proper incisions for opening tendon-sheath infections of the thumb and little finger, with ulnar bursal extensions of pus in the forearm This patient made a complete recovery with function and left the hospital at the end of one month Function was complete at the end of three months

Concerning drainage in these wounds, it has been my experience that when incision has been made in this manner no drainage material is necessary in the majority of cases. If it is desired and there is no hemorrhage, I insert strips of rubber dam, while if there is hemorrhage, small strips

of gauze thoroughly saturated with vaseline are packed into the wound

It seems especially unsurgical to draw rubber tubes or gauze under the transverse carpal ligament, and I would urge strongly that their use should be avoided. The drainage is not improved and pressure necrosis is favored. Moreover, where drainage at the wrist is unsatisfactory, I have had little cause to be displeased with the splitting of the transverse carpal ligament No case has been seen in which I felt that that procedure *per se* had resulted in loss of function, and I have frequently seen entire restoration of function after it had been cut. Details of the primary dressing and after-treatment are discussed later in this chapter

When the radial bursa becomes involved secondarily to the ulnar bursa, it should be treated as a primary radial bursal infection, which we will discuss below The treatment of osteomyelitis, involvement of the wrist-joint, secondary hemorrhage, and other sequelæ will be discussed in the chapters treating with Complications and Sequelæ

Treatment of Inflammation of the Tendon Sheath of the Long Flexor of the Thumb

Here it is my custom to dissect down to the tendon upon the flexor surface of the proximal phalanx, after entering the sheath, the incision is enlarged along the sac through the thenar eminence, separating the muscular mass (heads of the flexor pollicis brevis). It should be remembered that the tendon lies nearer the palm than one would be inclined to think, and that the mass of the thenar muscles lies to the radial side of the incision This incision is carried to within a thumb's breadth of the lower border of the transverse carpal ligament I limit the incision at this point, since with the assistance of Professor P T. Burns and Dr. A T Horn, at the Anatomical Laboratory of the Northwestern University Medical

School, I made a careful examination of 85 cadaver hands, with the result that it was shown that the motor nerve to the thenar muscles passes across the sheath between this point and the lower edge of the transverse carpal ligament, and in my opinion loss of the flexor pollicis

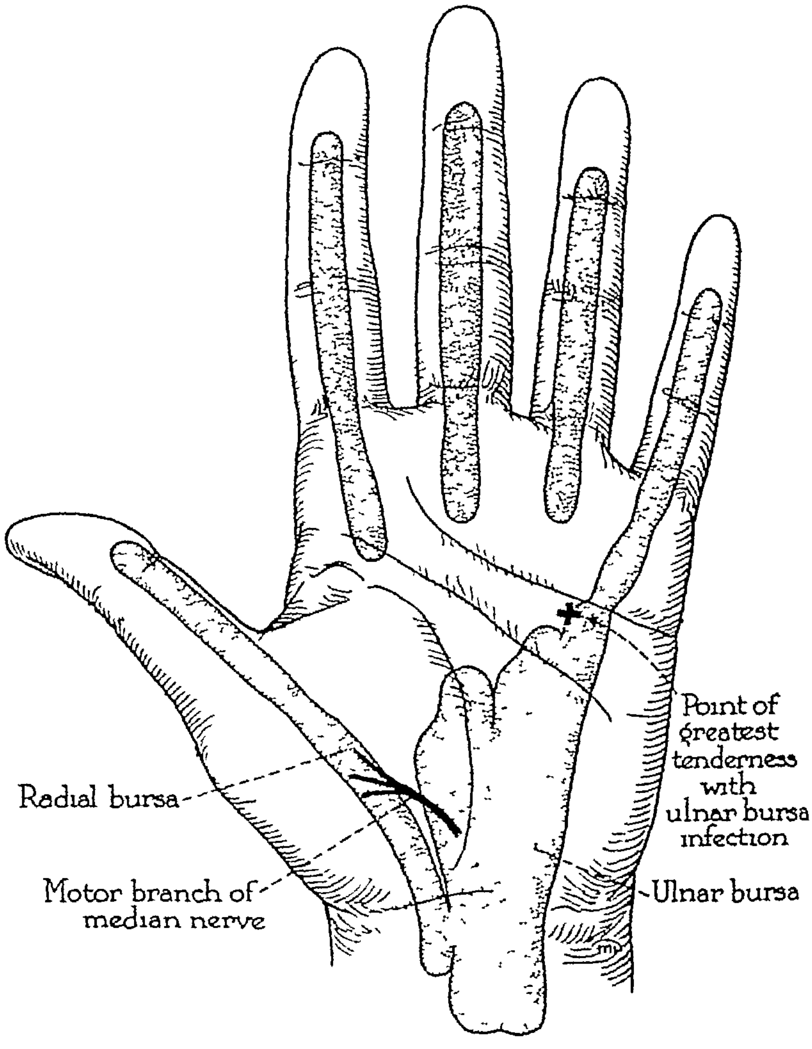


FIG 156—Relation of the motor branch of the median nerve to the radial bursa Note that it would be severed if the incision should be carried too far proximally (Kanavel and Mason, Cyclopedia of Medicine, F. A Davis Company)

longus tendon is to be preferred to destroying this nerve and thus bringing about a loss of function of the muscles which it supplies. Drainage of the upper end of the radial bursa is best carried out by the methods described above when discussing drainage of the upper end of the ulnar

bursa An incision is made laterally at the flexor surface of the ulna, and exceptionally another may be added on the radial side The ulnar incision is preferred because of the great probability that the ulnar bursa will be sequentially involved from the radial bursal infection, and because of the fear of injuring the radial artery in the radial incision The treatment of the proximal end of the radial bursa and the deep forearm extension is the same as that just described when considering the infection from extension of the ulnar bursa into the forearm

At times an accumulation of pus will be found on the forearm subcutaneously just above the wrist upon the radial side When this is opened the surgeon may be of the opinion that the sheath has ruptured and is thus draining anteriorly, hence, he will desist from drainage of the deeper tissue Such an accumulation is of lymphatic origin and has no connection with the sheath, so that the lateral incisions described above should always be made in addition to this skin incision in front

At times, owing to necrosis of tendons or extensive suppuration among them, it may be advisable to drain the sheath from the front, in which case an incision is made going ¼ inch to the radial side of the median line of the flexor surface of the forearm The dissection is carried down to the radial side of the flexor sublimis tendons, avoiding the median nerve which lies to the ulnar side of the incision The tendon sheath has generally ruptured by this time, or can be identified by a grooved director or fine probe passed from the opened sheath below It is entirely safe to cut the upper part of the transverse carpal ligament (Fig 149)

In almost every case, however, I feel that this anterior incision should be limited to opening the subcutaneous accumulation if there be any, and the tendon sheath should be opened by the lateral incisions described above for entering the space between the flexor profundus tendons

and the pronator quadratus Good-sized incisions should be made, so that drainage may be free.

In many cases where the infection has been severe or the tendon impaired primary removal of the tendon should be favored. This is particularly liable to die and remain for many weeks, causing the infection to persist and jeopardize other structures, so that if the tendon is at all destroyed or the infection shows a slow recovery it should be removed at once

In relation to *secondary ulnar-sheath infection*, it may be noted that there is doubt frequently as to the diagnosis in these cases In such cases it is advisable to dissect down carefully upon the sheath in the distal third of the palm just to the radial side of the hypothenar space After the palmar fascia is cut, a pad of edematous fat will be seen to bulge into the wound as if there were great tension in the subaponeurotic palmar space This fat having been dissected away, the tense bursa will be seen to bulge into the field if it is involved This is opened and the operation proceeds as described above while discussing the technique of treatment of the ulnar bursal infection. There is always a grave decision to make as to whether or not the sheath of the little finger tendon has become involved, and in case of doubt it should also be opened. In many cases of ulnar bursal infections secondary to radial bursal infections it escapes The treatment of involvement of the thenar space will be discussed in the next chapter. Involvement of the carpal joint is considered in the chapter on "The Complications of Infections."

The case of Mr W is reported, since it is a typical example of a virulent case of tenosynovitis beginning in the thumb and extending over by way of the tendon sheath of the flexor pollicis longus to the ulnar bursa The infection was virulent and the toxic symptoms so severe as to threaten the patient's life. The result was very satisfactory considering the fact that the patient did

not come under observation until after the sheath had been involved for at least thirty-six hours. In this case there was a complete restoration of function of the entire hand and fingers, with the possible exception of slight loss of flexion of the distal phalanx of the little finger This result is in marked contrast to those cases of similar nature which I have seen several days after the sheath had become involved, when such destruction of the tendons and their coverings had taken place as to preclude the possibility of a favorable outcome no matter what the surgical procedure might be The history of the case is practically identical with one seen two months previously, which had remained eigth days without opening. The general health and resistance of the individuals were much the same The outcome in the first case which had been treated conservatively was most disastrous, the patient barely escaping with his life and ending with a functionless hand After observing these 2 cases so close together, and many others both before and since with such similar conditions, I cannot but feel that under these conditions conservatism is most inadvisable, and that the earliest possible opening of the sheath is indicated.

CASE XXI —Mr W , referred by Dr Colleran, Post-Graduate Hospital (Fig 157)

Patient gave a history of having run a splinter of wood into the distal phalanx of the thumb seven days previous to coming to the clinic This had been removed with a penknife, and later, at the end of five days, another splinter had been removed Three days before, he began to complain of pain over the course of the thumb and radial side of the hand The whole hand now became tender and swollen

On examination, temperature was 101° F , pulse, 96 The whole hand was found to be swollen on both the flexor and dorsal surfaces, as was also the forearm Concavity of the palm was still present Tenderness was most marked at the wrist-joint and slightly above on both the radial and ulnar sides There was tenderness also along the course of the ulnar bursa in the palm of the hand and over the tendon sheath of the little finger There was only slight tenderness in the palm of the hand. Tenderness was also found

over the course of the flexor pollicis longus There is no tenderness over the index, middle, or ring fingers, and none on the dorsum. On extension of the fingers, extension of the little finger and thumb caused marked pain, the ring finger slight pain, and the middle and index fingers very little pain

Diagnosis of tenosynovitis of the flexor pollicis longus, the intermediary sheaths at the wrist, and the ulnar bursa was made

Operation —General anesthesia, Esmarch's bandage applied Incision was made through the skin and subcutaneous tissue over the ulnar bursa in the lower third of the palm After cutting through



FIG 157 —Photograph showing the incision on the case of Mr W, splitting of the ulnar bursa and radial bursa and incisions above the wrist Accompanying photographs show result two and one-half months after treatment (See Case XXI)

the palmar fascia the fat bulged into the wound This was split and the bulging sheath was seen beneath This was opened and pus was found The sheath was then opened throughout its length from the base of the middle finger up to and through the transverse carpal ligament (Fig 157) Pus was found throughout An incision was then made in the forearm on either side at the level of the flexor surfaces of the ulna and radius, 1 inch above the transverse carpal ligament, an artery forceps was passed underneath the tendons of the flexor digitorum profundus A slight amount of pus was found here An artery forceps now opened the sheath of the ulnar bursa

at its upper end, passing into the space underneath the flexor tendons, and a finger enlarged the opening



FIG 158 —Photograph showing the dorsal right-angled splint used after incision in infection of the ulnar bursa In the photograph the hand has been loosened from the dressing so as to show the right-angled splint This dorsal "cock-up" splint prevents prolapse of the tendons and maintains the "position of function," that is most important in securing a useful hand Infected hands should not be dressed with the fingers and hand straight except as noted in special instances to prevent prolapse of tendons The thumb-arm may be added, as shown in the chapter describing various splints

An incision was made over the proximal end of the proximal phalanx of the thumb into the sheath of the flexor pollicis longus A small amount of slightly turbid fluid was present that was not

clearly pus The opening was extended, however, to the distal end, where considerable pus was evacuated The incision was then extended upward along the sheath to within a thumb's breadth of the lower border of the transverse carpal ligament Free pus was found here also An artery forceps was then passed along the sheath up into the forearm underneath the flexor profundus tendons, communicating with the opening previously made.

After washing the sheath out thoroughly with normal salt solution strips of gauze saturated with vaseline were laid between the cut edges of the skin in the palm and also drawn transversely underneath the flexor profundus through the forearm incisions Hot boric dressings were applied

Subsequent Course —Pain was immediately relieved, temperature fell to 99° F , around which it remained, at no time going higher than 100° F , and the patient made a gradual and satisfactory recovery At the end of twenty-four hours the hot boric acid dressings were changed for dry dressings, the inner layer of which was saturated with vaseline The strips of gauze between the edges of the wound were removed, the hand was dressed in dorsal extension on a right-angled dorsal splint (Fig 158)

Subsequent Treatment —Each day the hand was dressed, each of the articulations was moved, including the finger-joints and wrist, and the hand dressed in dorsal extension On the fifteenth day it was deemed advisable to open the tendon sheath of the little finger, which had not been opened at the time of operation A small amount of pus was evacuated, and I believe it would have been advisable to have opened this sheath at the time of the primary operation The incisions over the flexor pollicis longus were completely healed at the end of three and a half weeks Those above the wrist closed at the end of five days That over the tendons of the ulnar bursa was completely closed at the end of four and a half weeks All that time the patient could move slightly all the fingers of the hand, and flex voluntarily, with the exception of the little finger, every joint, including the wrist He was urged to use his hand repeatedly and to return for passive motions In this respect he was somewhat dilatory At the beginning of the sixth week his hand was treated daily in the Klapp apparatus for breaking up adhesions and at the end of the ninth week he began to work with his hand, and at the end of the twelfth week he had practically complete function of all joints and fingers, with the exception of the little finger, where there was only 25 per cent of function. This will improve, but will never be perfect (Fig 157).

Later experience has taught me that active movements of the fingers should have been begun at once following the incision.

The following case of acute streptococcic infection of the sheath of the flexor pollicis longus is reported in some detail, since it is one in which the patient narrowly escaped with her life, and shows the course in these cases, and because the sheath ruptured permitting involvement of the major forearm space without involvement of the ulnar bursa

The complete restoration of the tendon function in this case is most encouraging I believe that with an early incision, followed by careful aseptic treatment, we can hope for much better results in the future than in the past

CASE XXII —Dr S , seen in consultation with Dr Besley, gave the following history which is abbreviated from the history sheets of the hospital

January 23 Pulse, 100, temperature, 101 8° F , respirations, 26 Hot dressings applied to right arm, under nitrous oxide anesthesia, Dr M L Harris incised the flexor surface of the thumb Condition good

January 24 Pulse, 80, temperature, 98 6° F , respirations, 20 Slept fairly well Condition seems very much improved

January 26 Leukocytosis, 11,000

January 27 Pulse, 64, temperature, 98° F , respirations, 20 Entire thumb swollen and pus oozes from incisions Thumb again incised by Dr Charles Davison, drainage inserted Normal salt enemas given every four hours, hot boric acid solution to part, 5 P M , pulse, 80, temperature, 101° F , respirations, 20

January 29, 4 A M Pulse, 108, temperature, 102 8° F , respirations, 26 8 A M , pulse, 80, temperature, 103 4°, respirations, 22, leukocytosis, 21,000 Thumb irrigated with hot boric and peroxide, dry dressings applied, 9 P M , temperature, 102 2° F , palm of hand greatly swollen and angry red extending into wrist Vomited small amount of fluid

January 30, 9 A M Temperature, 101 6° F , nauseated and vomited greenish fluid, face flushed, slept very little

January 31, 9 A M Temperature, 101 4° F , pulse, 96, respirations, 20 Swelling on hand increasing and extending, under gas-ether anesthesia Dr F A Besley made an incision into the radial bursa, liberating yellowish pus Rubber drain inserted, allowing free drainage between first and second metacarpals Small incision made above wrist, but no pus found in arm, although there was considerable redness and swelling

February 1. Pulse, 84, temperature, 102° F , respirations, 20 Slept some since 10 P M Pain in hand Hot dressings Smears from pus show short chains of streptococci

February 2 Temperature, 101 6° F , leukocytosis, 24,000 Feels rather drowsy Does not have much pain Slept at intervals

February 3 Pulse, 84, temperature, 100 2° F , respirations, 20 Cultures on agar and in bouillon show only streptococci, leukocytosis, 32,000 Under gas anesthesia incisions enlarged and opened wide by forceps by Drs Besley and Kanavel

February 4, 1 A M Pulse, 80, temperature, 102° F , 9 P M , temperature, 101° F Slept most of forenoon

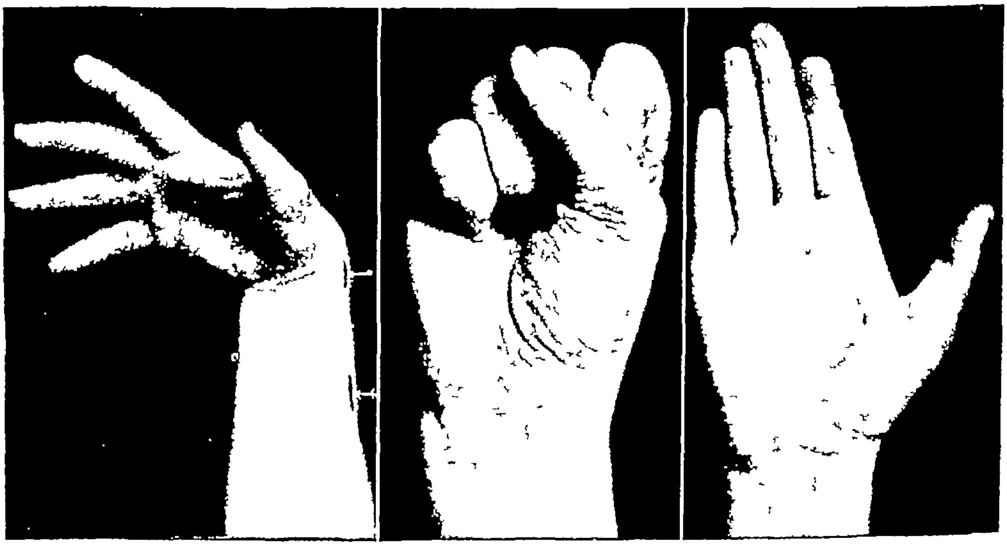


FIG 159 —Photograph showing the function present in Case XXII, infection of the radial bursa, three months after treatment

February 5, 10 A M Temperature, 102° F Hand dressed Swelling, hyperemia, and tenderness along flexor surface of arm, radial side Pus oozes from wounds Good night's rest, 4 P M , pulse, 112, temperature, 103° F , respirations, 24 Another incision made in forearm by Dr Besley The incision was made on radial surface of arm, and liberated a large quantity of yellow pus Gauze packing inserted Gas anesthesia 7 30 P M , gauze packing removed Patient rather restless

February 6 Pulse, 92, temperature, 102° F ; respirations, 20

February 7 Pulse, 90, temperature, 99 4° F , respirations, 20 Patient very comfortable Small superficial pocket of pus on anterior surface of wrist opened by Dr Besley

February 8 Pulse, 80, temperature, 98° F , respirations, 20 From this time on the temperature remained normal Patient

gradually improved, and was discharged February 24 The wound in the thenar space closed about two weeks later

Subsequent History —At the end of five months the case presents a complete restoration of function of the muscles of the thumb and the tendon of the flexor pollicis longus, and the tendons of the hand upon flexion (Fig 159)

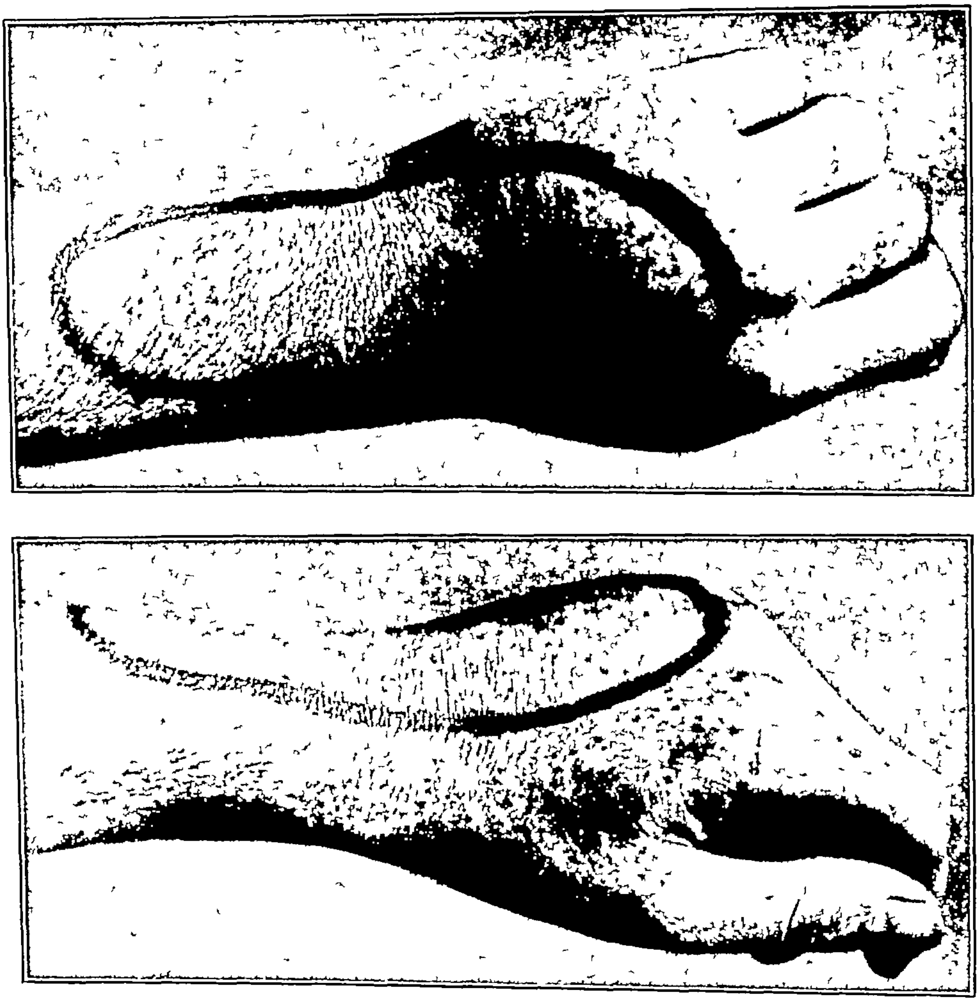


FIG 160 —Acute suppurative dorsal tenosynovitis Note the area of surrounding edema The tendon sheath is only about one-half the length of the tumefaction

SYNOVIAL SHEATHS ON THE DORSUM

When the synovial sheaths upon the dorsum are infected, a simple splitting of the sheath throughout its length appearently gives the best results (Fig. 160). I have had only a few of these cases due to acute infection, and they all recovered with good function after a short

time, with the exception of the case in which this involvement was associated with a palmar infection, when a fatal issue followed (Case X)

AFTER-TREATMENT OF SUPPURATIVE TENOSYNOVITIS

Drainage.—The use of drainage has been discussed by every surgeon, and the principles underlying it here are the same as elsewhere. Those who after much experience and thought have decided upon its use will probably use it here My own results have led me to abandon it almost entirely. I never use a rubber tube, owing to my fear of pressure necrosis Gauze, if left in many hours, begins to act as a plug. Unless there is bleeding, it is not used If, however, one fears that the skin will close down at once and prevent the escape of pus, strips of rubber-dam made from an old rubber glove are inserted but, if there is much venous oozing, gauze saturated with vaseline is used I have found this to give good drainage and not to act so much as a plug, yet giving tampon pressure in cases of oozing Strips may be inserted from the sides above the wrist under the flexor profundus, and also above into the ulnar incision on the forearm. In most cases all drainage material if used is omitted after thirty-six to forty-eight hours If the incisions have been large enough it is not necessary, moreover, repeated insertion of drainage favors the introduction of bacteria of other types *Careful aseptic dressing is most important* since if staphylococci are introduced the symbiosis is liable to cause necrosis of tendons and prolonged convalescence

In the virulent cases, every attempt is made not to manipulate the arm and hand any more than is necessary, until the danger of systemic infection is passed, so as to protect the patient against absorption of toxins as much as possible. The application of the Bier method of constriction of the arm to prevent the rapid absorption

of bacteria and toxins during and immediately after incision has already been touched upon The arm is kept immobilized and slightly elevated This latter is done to secure comfort as much as to aid in recovery. The von Volkmann treatment, *i. e*, vertical elevation of the hand, has not seemed to me to be of great therapeutic value, although apparently it is a valuable procedure in that it prevents excessive edema in the later stages

For the first few days after incision it would appear that hot, moist dressings are of value to relieve the pain and promote walling off of the infection After this stage they should be abandoned in favor of dry dressings, since they seem to produce excessive granulation. In most cases I have been able to apply dry dressings at the end of twenty-four to forty-eight hours The hot, moist dressings are generally made from a saturated solution of boric acid However, it is probable that the moist heat is the essential factor Strong antiseptic solutions, such as bichloride and carbolic acid, are never used The inner layer of the dry gauze may be saturated with vaseline to prevent its adhering to the wound. As soon as the moist hot dressings are discontinued I bake the hand under the exposure of an electric light three to four hours each day and apply only one or two thicknesses of gauze as a dressing

The hand is dressed from once to twice daily If gauze has been inserted and has adhered to the wound, there is less shock produced by anesthetizing the patient with a small amount of nitrous oxide than is given by the pain incident to withdrawal without such an aid

I ordinarily mold a plaster-of-Paris or use an aluminum splint to fit the back of the forearm and hand At the wrist the splint is bent backwards to hold the hand in the "cock-up" position This places the hand in the "position of function" and, even though tendons should be lost or adhesions ensue, some function is retained The fingers

time, with the exception of the case in which this involvement was associated with a palmar infection, when a fatal issue followed (Case X)

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If it is evident that a tendon of one of the fingers will be lost a metal splint should be placed on the dorsum of the hand with an arm extending over the dorsum of the affected finger so as to hold the finger and the individual phalanges flexed at about 45 degrees, *i e*, in the "position of function" If fibrous ankylosis takes place in this

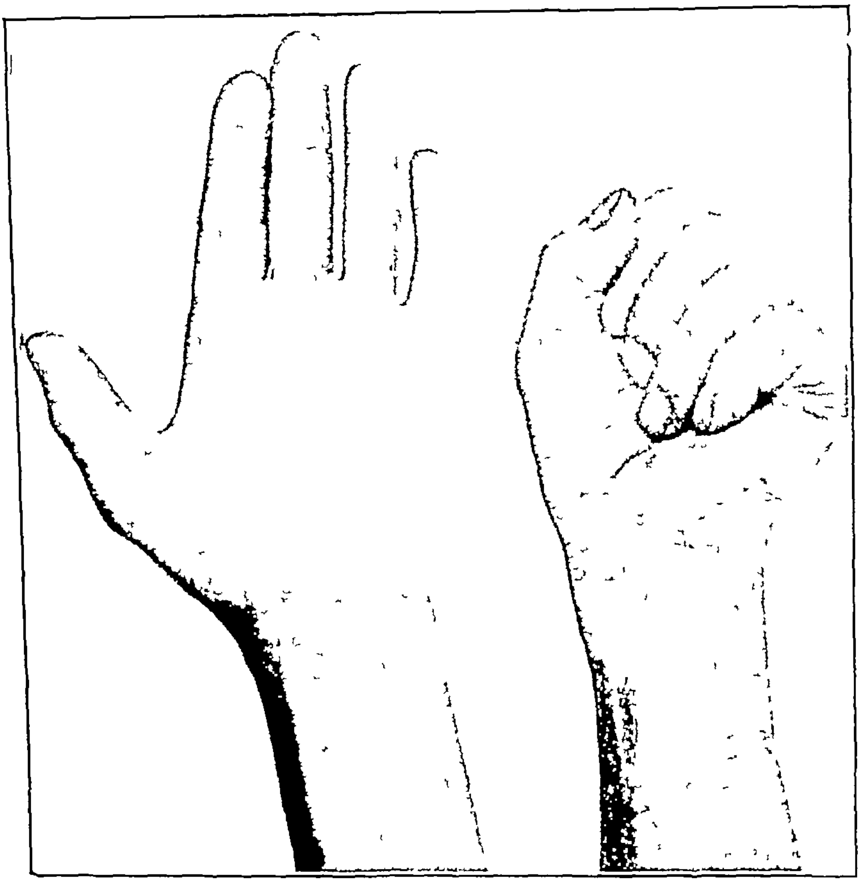


FIG 162 —Photograph of result one month after incision and active early treatment of an infection of ulnar and radial bursæ with extension of pus into forearm Incision five days after the infection had fully developed Amputation had been advised by his physician

position it will still be a useful finger Except in those cases where the tendons are lost and fixation in "position of function" is desired, the splint is removed daily for physiotherapy

The prevention of adhesions in the joints, preservation of the vitality of the muscles and the use of the tendons

are held semiflexed, except in those cases where such a long incision has been made that the tendon tends to prolapse in the bow-string position, here the involved finger is splinted in extension. The thumb is held abducted from the flexor surface of the hand and rotated so that the flexor surface of the thumb is opposite the flexor surface of the distal phalanx of the index finger This is done either by inserting a roller bandage between the thumb and index fingers and holding it by adhesive plas-

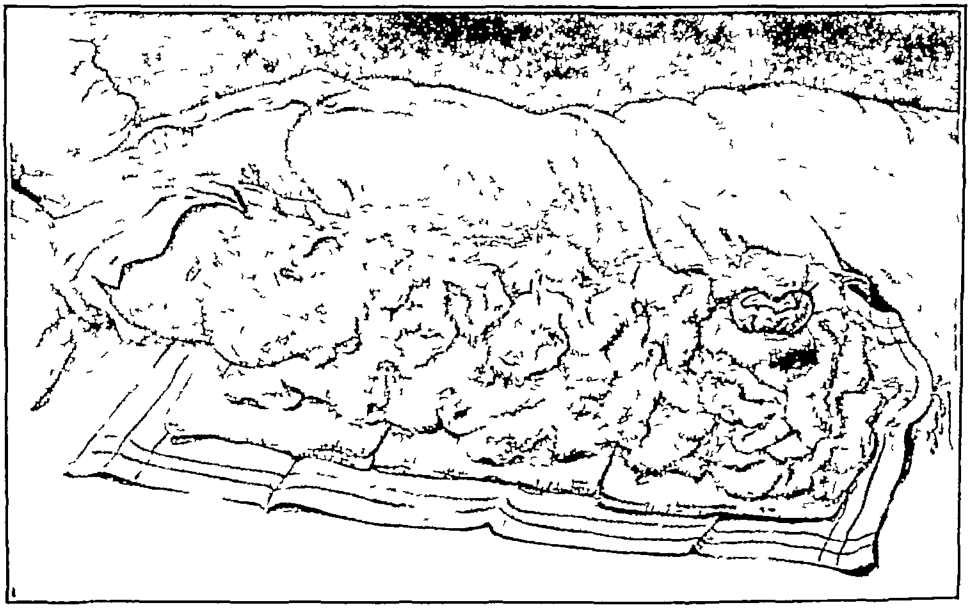


FIG 161 —Application of a hot moist dressing Note the hand held in the "position of function" by the gauze roll in the hand and that the dressings are voluminous and extend to the shoulder (After Kanavel and Mason, Cyclopedia of Medicine, F A Davis Co)

ter, or if this is impossible because of interference with drainage, and this is generally found to be true, a metal arm is incorporated in the dorsal splint extending out and around in such a manner as to permit fixing the thumb in this "position of function" Hands should never be permitted to lie simply extended in dressings—one cannot urge too strongly the importance of maintaining this "position of function" Special attention is directed to the discussion of this subject in Chapter VII

CHAPTER XXIV

THE TREATMENT OF MAJOR FASCIAL-SPACE ABSCESSES.

WE shall here consider the treatment of fascial-space abscesses without discussion of the tenosynovitis which often precedes them When confronted with such a complication the surgeon should consult the preceding chapter and the treatment of the combined lesions will be readily understood

The treatment naturally divides itself into prophylactic and active. In the first instance all wounds should be given aseptic care, and any localized infection should be attended to, thorough drainage being instituted before the infection has a chance to spread This, however, is not a plea for incision "as a prophylactic precaution" or in the absence of a definite diagnosis of an accumulation of pus. Whenever the surgeon makes an incision and evacuates only serum he has harmed the patient. In those cases in which we are waiting to decide whether or not a localized abscess is present, immobilization and the local use of the well-known hot, moist dressing is probably more efficient than any other application Conservatism is more justifiable here than in tendon-sheath infection—and again let me emphasize that pus is seldom found on the dorsum of the hand The usual general tonic and excretory procedures should be instituted

Should the diagnosis of a localized accumulation of pus in any of the various tissues be made, our first question is, What is the best site for incision? We need not discuss the fact that such a condition as that demands early and efficient drainage Should the subcutaneous tissue of the

are most important Unfortunately the surgeon so often sees these cases late after primary incisions have been made that the result falls short of what could be secured with efficient treatment In the severe fulminating types this has permitted such destruction of the tendons and synovial coverings as to make any after-treatment of little avail It seems to me advisable to *begin passive and active movements within a short time after primary incisions;* in other words, as soon as the danger of systemic infection is over, ordinarily inside of three or four days after the primary incision I do not believe that the local condition is made materially worse, and we do aid in the prevention of firm adhesions It is better to do this aseptically in baths of very hot water, which relieves the pain to some extent and helps to cleanse the discharging wound. The patient's hand and forearm being immersed in hot sterile water, the surgeon with glove-covered hands gently flexes and extends each finger, as well as the hand at the wrist, several times Violent movements are not indulged in The bath is not kept up any length of time, since we wish to prevent rather than to favor the development of granulation tissue at this stage The patient is encouraged to make active movements himself If a dry, hot chamber is at hand, this may be used to advantage *I cannot emphasize too strongly the importance of this early, gentle, and intelligent manipulation* I do not refer to massage, but to the intelligent use of the various joints, muscles, and tendons

General principles of treatment applicable to all cases are discussed in Chapter VIII

A consideration of the treatment of the complications and sequelæ will be found in Chapters XXVI and XXVII

A discussion of after-treatment in these patients will be found in Chapters XXVIII, XXIX, and XXX

proximal flexion crease, or, grossly speaking, a thumb's breadth and a half up into the palm This brings the incision between the tendons An artery forceps is thrust under the group of palmar tendons and the blades opened, satisfactory drainage ensuing A small strip of rubber-dam will keep the opening from closing for a

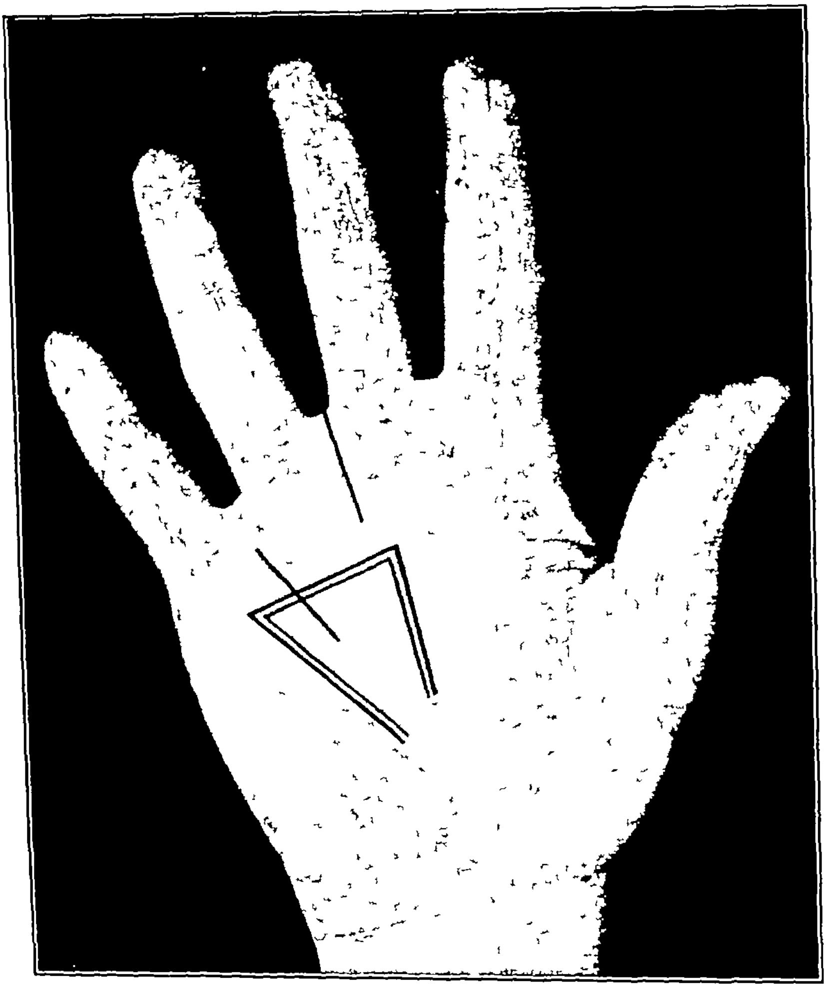


FIG 163 —Typical incisions for opening the lumbrical space and for opening the lumbrical space in conjunction with the middle palmar space

day, after which time it will not be needed It is remarkable how rapidly patients will recover under this treatment

Herewith is reported the first case in which I used this method I have used it many times since with absolute satisfaction.

dorsum or the areas under the epidermis or dermis of the palm be involved, or minor infections of the thenar and hypothenar areas be present, a wide opening by simple incision is generally sufficient. Should the middle palmar, thenar, lumbrical, or subaponeurotic spaces be involved, however, some special consideration is necessary.

THE MIDDLE PALMAR SPACE

Technique of Treatment.—It is probably better to err upon the side of radicalism, than conservatism, when confronted with a middle palmar-space abscess, owing to the liability of complications in the ulnar synovial sheath, the nerves, the bones, and the joints, if the abscess is neglected.

Any method of opening the space exposes certain tissues to injury, and it is a question of choosing the least dangerous route It cannot be opened upon the ulnar side, owing to the fear of infecting the ulnar bursal sheath, a flap of the palmar fascia should not be dissected up from below, as has been suggested, making a sort of trap-door, as it were, since the infection lies below the tendons, and to make such an opening and then drain anteriorly between the tendons would result in unnecessary adhesions

The least injury and the most efficient drainage of the middle palmar space can be secured by an incision along one of the three lumbrical canals leading into this space, *i. e.*, the little finger, ring finger, or the middle finger canals (Fig. 163). That canal will be chosen which is already markedly infected, either because it has been the atrium of the infection or because it has been secondarily involved. If the surgeon has any choice in the matter, that between the ring and middle fingers gives the most satisfactory drainage An incision is made into the canal and carried ½ inch above its end up into the palmar space, *i e*, ½ inch proximal to a line joining the proximal end of the distal flexion crease with the distal end of the

of the right hand between the ring and little fingers An abscess had formed in the fascial space at the base of these fingers and extended along the lumbrical canal Upon investigation it was found to have involved the middle palmar space This was diagnosticated by the tenderness localized over the lumbrical canal, and the bulging of the palm associated with localized tenderness The incision was made at the original site of the infection, passing from the palm through the fascial tissue to the dorsum between the proximal phalanges of the fingers A grooved director was then inserted along the lumbrical canal, which was opened throughout its extent, the incision being carried up to the middle flexion crease of the palm, in other words, ½ inch above the lumbrical canal Forceps were now inserted underneath the tendons, opening the palmar space widely, about 1 ounce of pus escaped, no drain was inserted, hot boric acid dressings applied

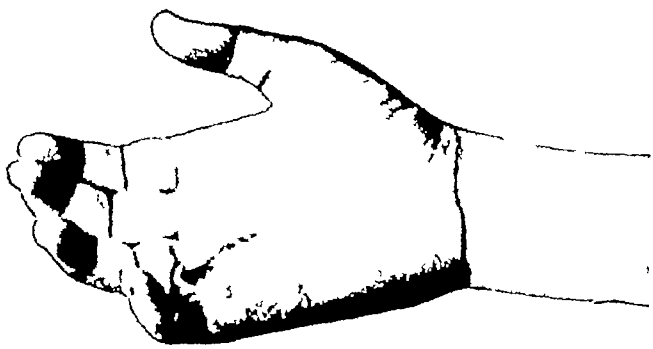


FIG 166 —Photograph of incision in a case of infection in the middle palmar space originating in web at end of lumbrical canal Recovery with complete function in ten days (See Case XXIII)

Course —At the end of ten days all discharge of pus had ceased and wound had healed At the end of three weeks complete function was present in all the fingers and hand (Fig 166)

THE TREATMENT OF COMBINED INVOLVEMENT OF THE MIDDLE PALMAR AND THENAR SPACES.

In uncomplicated combined involvement of the two spaces they may be opened and drained through the single incision ordinarily used for opening the thenar space. This avoids any incision in the palm. The incision having been made on the dorsum at the level of the flexor surface of the second metacarpal the forceps is carried across the flexor surface of the second and third meta-

CASE XXIII.—Frog felon of palm spreading along lumbrical canal into middle palmar space, incision along canal Recovery with perfect function



FIG 164 —Drainage of middle palmar space (*a*) through an incision along the lumbrical canal (Kanavel's film, "Diagnosis and Treatment of Infections of the Hand," courtesy of the Eastman Teaching Films Inc)

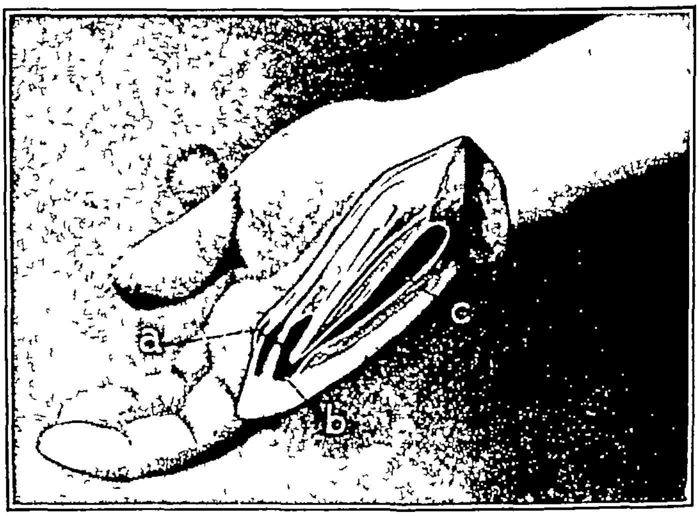


FIG 165 —Shows channel of infection passing from a frog felon in the middle palmar space along the lumbrical canal as in Case XXIII *a*, Subcutaneous pus, *b*, frog felon, *c*, middle palmar space

M R , treated at the Post-Graduate Hospital, July, 1906 Service of Prof F A Besley Five days before entrance patient developed an infection from the crack of a callus at the base of the palm

the palmar and thenar spaces at the proximal end, the point thus passing through the thenar space superficial to the adductor pollicis (transversus) and coming out on the dorsum between the metacarpal bones of the thumb and index finger (Fig 167) A rubber-dam drainage strip was then drawn through and left eighteen hours. Other incisions were made into the ulnar bursa and forearm.

CASE XXIV —Primary infection, cracks from callus on palm, extension into palm of hand, drainage of middle palmar space, thenar space, ulnar bursa, and forearm Recovery with perfect function

H , Post-Graduate Hospital Two weeks before coming to the hospital patient had developed an infection in the palm of the hand, evidently in the callus produced by tongs, while handling ice Two or three inadequate incisions had been made when the patient entered the hospital, with a temperature of 102° F and an enormous swelling of the entire hand and forearm, involving the palmar and dorsal surfaces The palmar fascia bulged up instead of presenting its normal concavity, while the thenar area was ballooned out as if inflated to its complete capacity There was redness and swelling upon the flexor surface of the forearm involving particularly the lower third The swelling upon the back of the hand was ascribed to edema The phalanges of the fingers were flexed at an angle of 45 degrees, while the metacarpal bone of the thumb was forced away from the hand and the distal phalanx of the thumb sharply flexed The diagnosis of pus in the middle palmar space, thenar space, the forearm under the profundus tendons, and the probable involvement of the common synovial sheath in the palm was made Owing to the inadequate incision already made in the palm, this was chosen as the proper site for exploration The incision having been carried through the palmar fascia, pus was found in the position designated, with an involvement of the ulnar bursa from the base of the little finger to the forearm The bursa was opened throughout its length, cutting through the transverse carpal ligament The major portion of the pus, however, lay outside the sheath An artery forceps was inserted under the tendons of the palm below the sheath and a large ostium made An artery forceps was then thrust through the partition between the thenar and middle palmar spaces at the base of the hand lying on the volar side of the adductor (pollicis transversus), coming out between the metacarpal bones of the thumb and index finger A drainage strip was then drawn through this space of the palm and left in eighteen hours The incision, which was carried through the transverse carpal ligament to the forearm, exposed a

carpal under the tendons and into the middle palmar space. The septum between the two spaces is ruptured widely by the forceps and rubber-dam drainage inserted

The treatment must vary with the complications present and can be best illustrated by quoting a typical

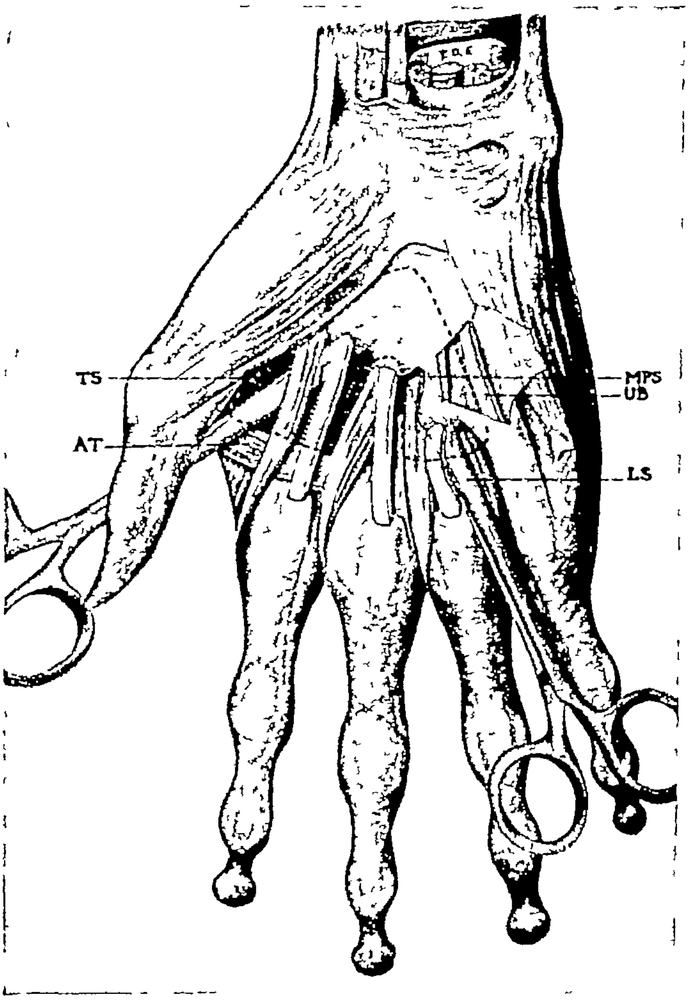


FIG 167 —Drawing showing the drainage under tendons *AT*, adductor pollicis (transversus), *LS*, lumbrical space, *MPS*, middle palmar space, *TS*, thenar space, *UB*, ulnar bursa

case In this case the middle palmar, thenar, deep forearm spaces with the ulnar bursa were involved The forceps was inserted into the incision already made into the middle palmar space and passed under the palmar tendons and pushed through the thin septum separating

large abscess lying underneath the tendons of the flexor digitorum profundus upon pronator quadratus and interosseous membrane An incision was made on the ulnar side of the forearm to open this space adequately Hot boric acid dressings were applied

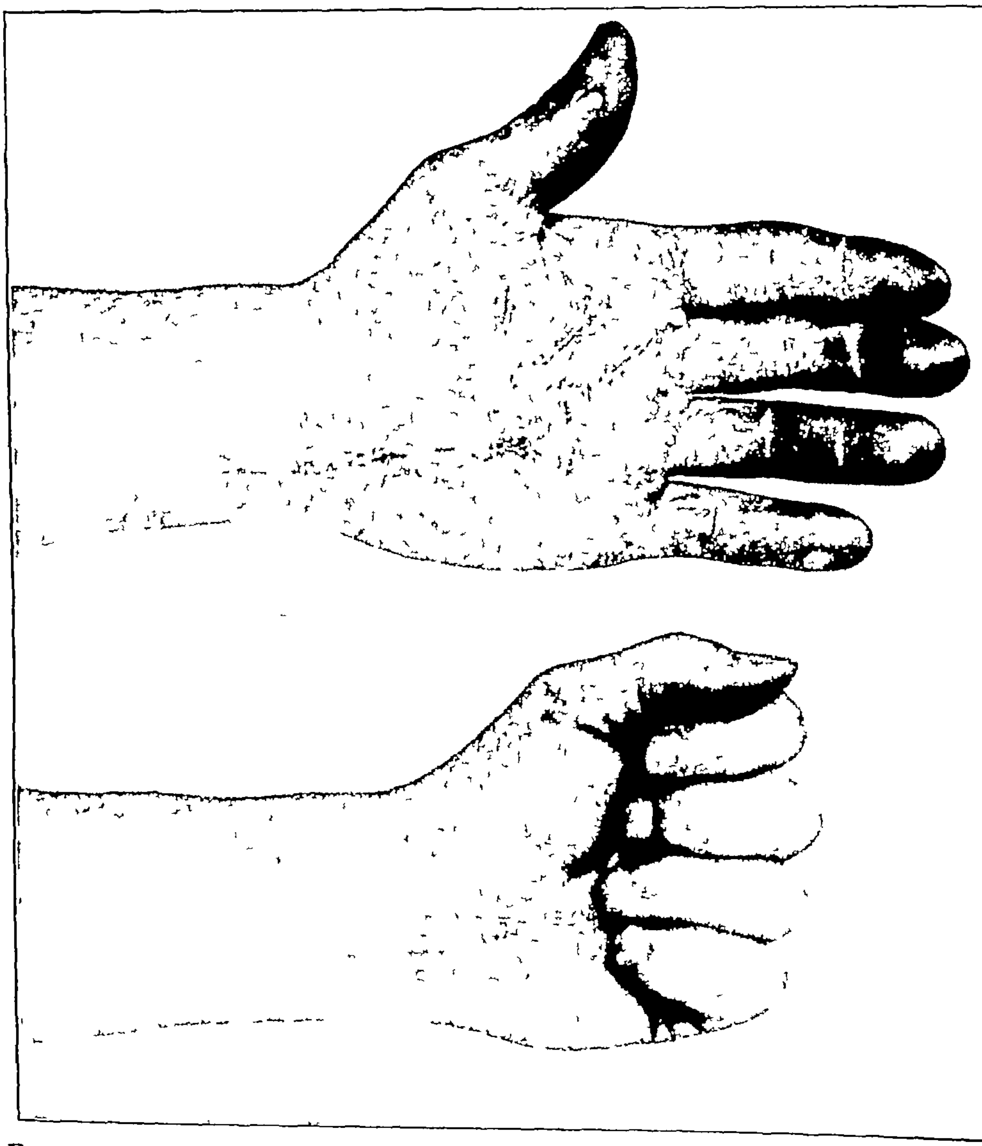


FIG 169 —Case XXIV, showing result three months after treatment Note perfect function

Course —Immediate subsidence of temperature and septic symptoms In ten days complete cessation of discharge, and in two weeks all wounds were healed In three weeks the patient was using his hand with 75 per cent of function, and in five weeks complete function was present, as demonstrated by accompanying photographs (Figs 168 and 169)

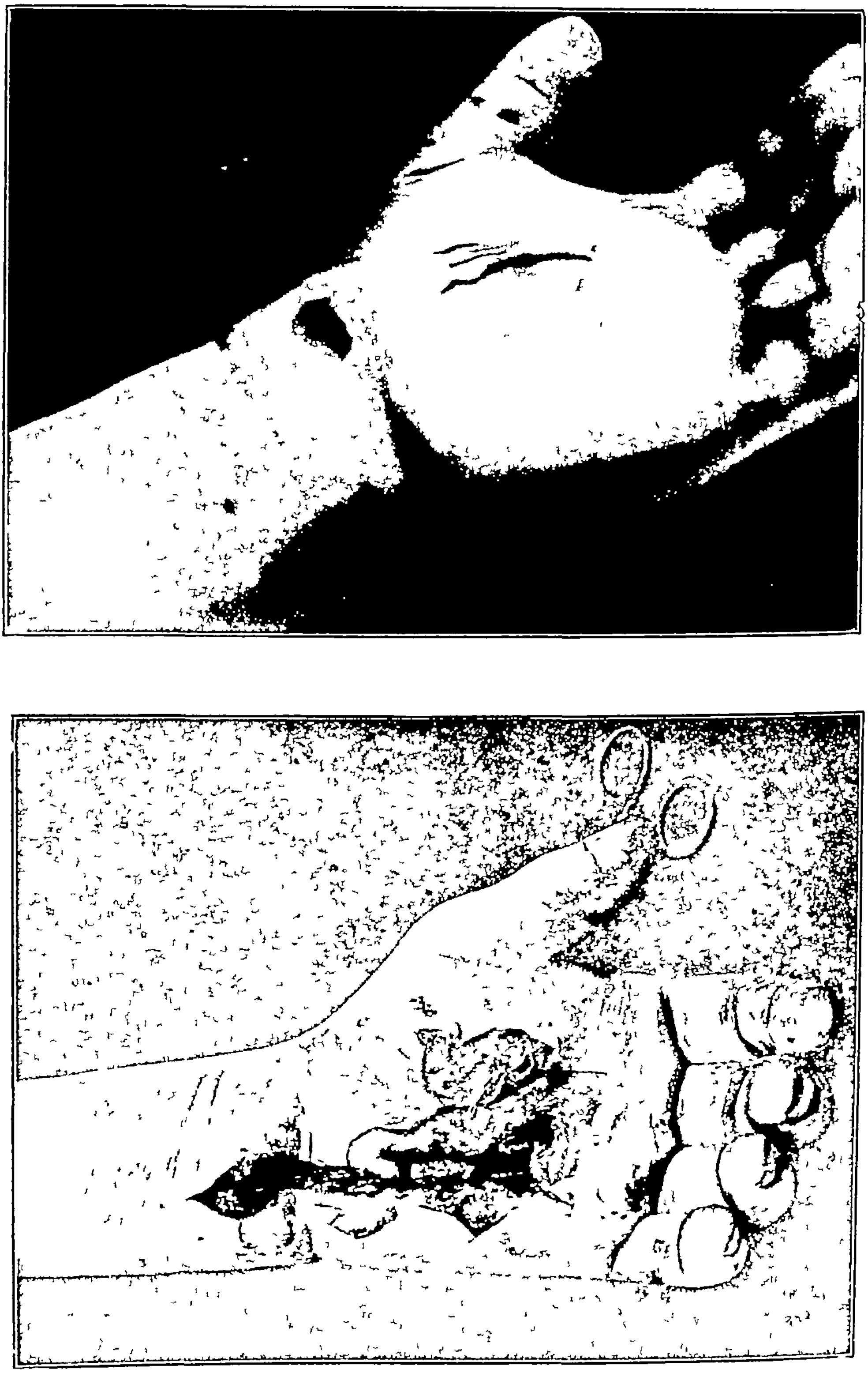


FIG 168 —Case XXIV before and after incision Note the artery forceps through from the dorsum into the thenar space In this case the transverse carpal ligament was cut

such cases the through-and-through drainage so much in vogue among the older surgeons is indicated Let us study where such drainage can be safely instituted if it is indicated Such a point should be chosen as will give the most satisfactory outlet to all the diverticula, and at the same time injure the fewest structures Here the value of our roentgen-ray plates, with the cross-sections and



FIG 171 —Roentgen-ray plate of injection mass in the thenar space, representing the location of pus when it occupies this space and its relation to the ulnar bursa

injections, is invaluable We see that the mass always lies over the interosseous space between the ring and middle fingers, and that an opening here will drain all the pockets (Fig 170) Our incision, however, must lie proximal to the transverse fasciculi of the palmar aponeurosis (See cross-section, Fig 118, roentgen-ray, Fig 172) Secondly, it must lie to the radial side of the ulnar bursa (roentgen-ray plate, Fig 171) and must be

This case was one of the worst that ever came to my notice. We were fortunate, however, in that no necrosis of the tendons had taken place The rapid and complete recovery can be ascribed only to the thorough opening of every pocket of pus by incisions that did not endanger previously uninvolved areas. We should also note that the transverse carpal ligament was cut, a procedure seldom or never necessary in uncomplicated mid-palmar abscess



FIG 170 —Roentgen-ray plate made from a hand in which the middle palmar space was injected with a mixture of red lead and plaster-of-Paris Photograph represents location of pus in typical middle palmar space infection

THE TREATMENT OF COMBINED INVOLVEMENT OF THE MIDDLE PALMAR AND SUBAPONEUROTIC SPACES.

At times we will have infected crushing injuries of the hand in which the metacarpal bones are fractured Here the *subaponeurotic space on the dorsum is involved in conjunction with the middle palmar space* (Case XV) In

injured at this site, but also the most perfect drainage is instituted

Now let us consider where an incision should lie in this space An examination of the roentgen-ray picture (Fig 172) shows the deep palmar arch running across this area, at the upper end, the fine lines drawn transversely represent the dense transverse ligaments of the heads of metacarpals while the curved lines represent the palmar creases It is thus seen that at the point where the middle palmar crease crosses the metacarpal space should be the indicated site for drainage Making a cut here through the palmar aponeurosis, and then forcing a pointed artery forceps through to the dorsum, being careful to rupture the dorsal aponeurosis freely, we draw through a large twisted rubber-dam strip At this site there is little danger of a pressure necrosis of the ulnar bursa or the palmar arches

If there is a necrosis of the metacarpal bones they may be removed subperiosteally with subsequent regeneration and no impairment of function due to their temporary loss

TECHNIQUE OF TREATMENT OF ABSCESSES IN THE THENAR SPACE

Should the thenar area be involved, the indications for radical operation are absolute, even upon less evidence than in the case of palmar infection, since the consequences of opening the space, even though uninfected, are not serious (see Case V, in which space was opened when uninfected, under mistaken diagnosis) Here the pus lies either volar to the adductor pollicis (transversus), or upon both its dorsal and palmar surfaces Theoretically, the most available place to open would lie to the radial side of the index metacarpal, where a free incision would drain both in front of and behind the adductor We therefore make an incision through the dorsum, on the

to the ulnar side of the middle metacarpal, or it will enter the thenar space This again throws the incision into the

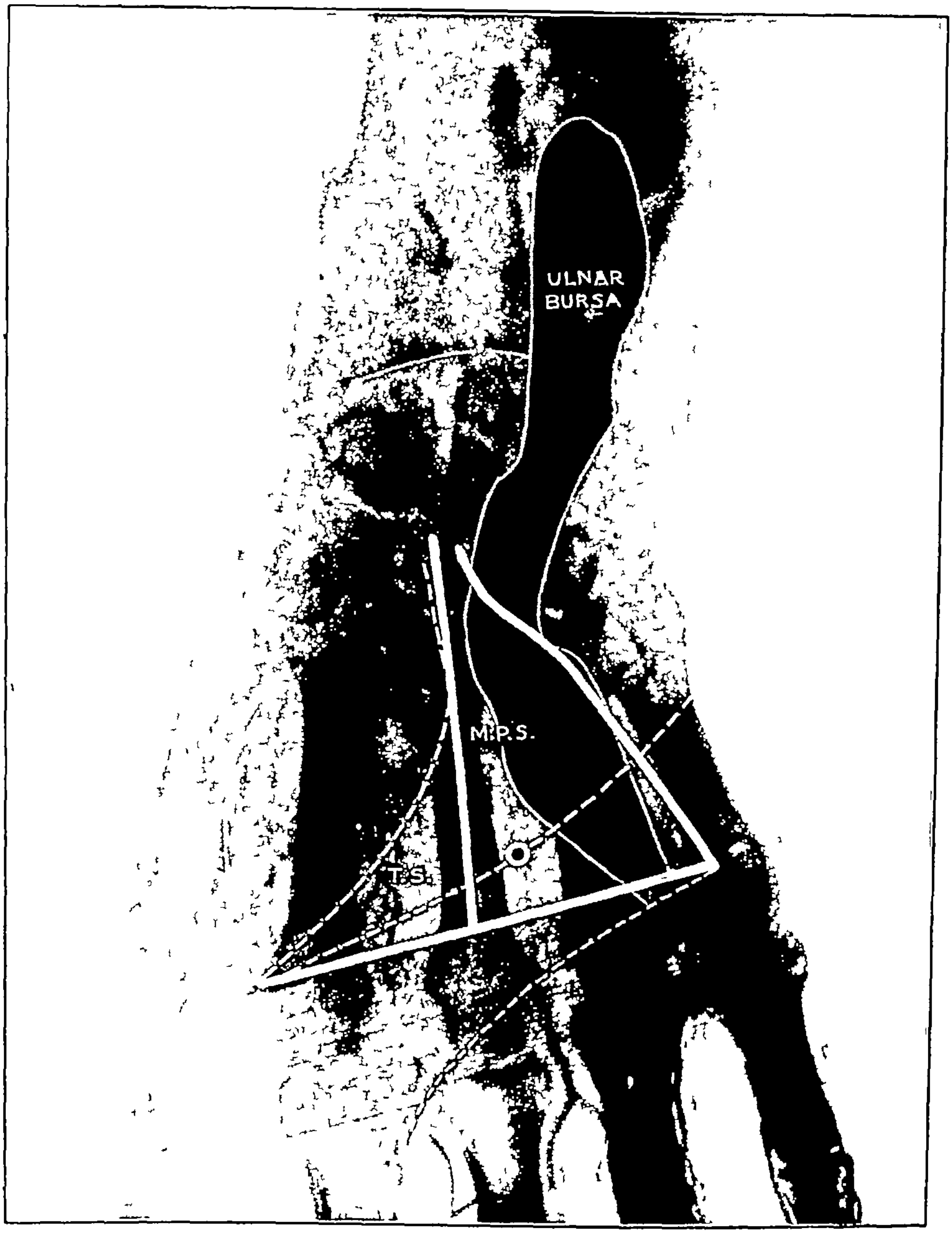


FIG 172 —Roentgen-ray picture showing the boundaries of the thenar (*T S*) and middle palmar spaces (*M P S*) marked and the proper site for opening the latter or for drainage through to the dorsum indicated by the circle The ulnar bursa and bloodvessels are injected

metacarpal space, between the middle and ring fingers Thus we see that not only are the fewest structures

for treatment There was considerable swelling of the whole hand, but distinctly greater upon the radial side Dorsal thenar area had slightly greater swelling present than palmar thenar area Upon inspection it was not difficult to see that the thenar area, as a whole, was much more swollen than the remainder of the hand Adduction thenar crease was the dividing line Thumb metacarpal fully abducted, proximal phalanx semiflexed, distal phalanx fully flexed, giving an almost spastic look to the hand The finger pha-



FIG 174 —Showing incisions made upon the dorsum of the hand That upon the thenar space is made to drain the thenar space in the palm Those upon the distal part are made to drain extensions from the palmar space to the dorsum and the so-called collar-button abscesses when they extend to the dorsum

langes were all semiflexed The flexion of the index finger, however, was more rigid than that of the other three, and movement of it and the thumb caused more pain than the three ulnar fingers Both epitrochlear and axillary glands slightly enlarged and tender Old incision upon dorsal thenar region, from which small amount of pus was exuding. Temperature, 101° F , pulse, 90 Tenderness marked over palmar thenar area

radial side of the index metacarpal and opposite its middle, and on a level with its flexor surface An artery forceps is then thrust into the thenar space across the flexor surface of the index metacarpal This gives perfect drainage and leaves no scar upon the flexor surface of the hand Care should be taken not to pass the artery forceps beyond the middle metacarpal bone, for fear of spreading the infection to the middle palmar space (Fig 167)

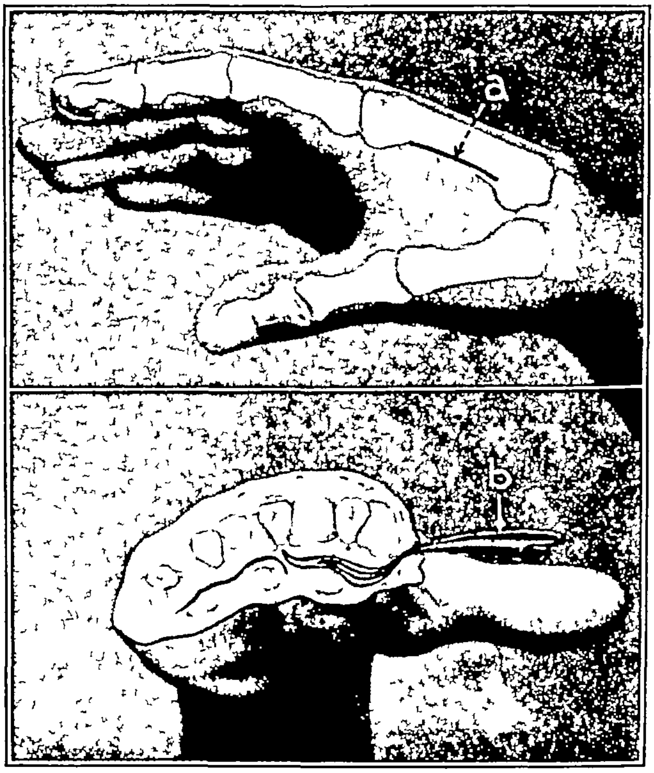


FIG 173 —Drainage of the thenar space Site of incision (*a*) and drain (*b*) inserted into this space (Kanavel's film, "Diagnosis and Treatment of Infections of the Hand," courtesy of Eastman Teaching Films Inc)

Illustrating these facts, the following case may be cited:

CASE XXV —K , injured September The sharp point of a meat tongs ran into the thenar area upon the level of the extended thumb about 2 cm from the thenar adductor crease Pain and swelling ensued the following day On September 5, he consulted a physician, who found much redness and swelling upon the dorsal thenar area and made an incision there, but evidently failed to evacuate pus Hot dressings were applied, and two days later patient presented himself at the Northwestern University Surgical Dispensary

AFTER-TREATMENT IN FASCIAL-SPACE ABSCESSES

After any of these procedures the usual hot, moist dressings are applied until we feel that extension of the process has ceased, when they should be abandoned, since the continuation of the enlargement of the vessels incident to their use results in increasing edema and ultimately lessening resistance, owing to improper circulation, hence they become a menace to the part rather than a help At this stage elevation of the part will be found to be of material aid Little or no drainage material is inserted, a strip of rubber-dam may be used for twenty-four hours, seldom longer Immobilization should be kept up as long as there is any danger of muscular action disseminating the infection. If any slough is present the instillation of Dakin's solution has in my hands been beneficial As soon as this stage has passed, however, active and passive movements should be encouraged at once, with the idea of assisting in the absorption of the excessive edema, as well as assisting in the prevention of tendon and joint adhesions I frequently begin these on the second day

The general considerations of treatment applicable to all cases are considered in the chapter on "The Principles of Treatment"

Diagnosis —Abscess, thenar space Operation Under nitrous oxide anesthesia incision made into thenar area at about the same site as the wound, much pus evacuated Gutta-percha drainage established, hot, moist boric dressings applied September 7, swelling almost subsided, still discharge of much pus Temperature, 99° F , pulse, 84 Treatment continued Cultures taken, typical Staphylococcus aureus colonies, methylene blue and Gram's stains, Staphylococcus aureus September 9, hand much better, drainage removed, hot dressings reapplied September 11, hand in good condition, dry dressings applied Following this, patient made a rapid recovery Seen July of the following year No contraction, function perfect

TECHNIQUE OF TREATMENT OF ABSCESSES IN SUB-APONEUROTIC SPACE

If the subaponeurotic space be involved, we should remember that the tendons proper in the lower part of the dorsum overlie the metacarpal bones, except the tendon going to the little finger, consequently our incision should lie over the interosseous space Moreover, any deep transverse incision, if too long, would cut the tendon, while a simple longitudinal incision would tend to close Therefore, in making our incision and drainage, these two factors should be taken into consideration and an adequate opening provided, which does not injure the tendon Those cases complicated by middle palmar-space infection have already been discussed

INFECTION IN THE MAJOR FOREARM SPACE

If the infection has spread up beyond the transverse carpal ligament into the forearm, the pus will lie beneath the tendons of the flexor profundus and upon the pronator quadratus in the space described as the major forearm space The best method of treating this abscess has been described when considering in the previous chapter an extension into this area from a suppurative ulnar bursitis

AFTER-TREATMENT IN FASCIAL-SPACE ABSCESSES

After any of these procedures the usual hot, moist dressings are applied until we feel that extension of the process has ceased, when they should be abandoned, since the continuation of the enlargement of the vessels incident to their use results in increasing edema and ultimately lessening resistance, owing to improper circulation, hence they become a menace to the part rather than a help At this stage elevation of the part will be found to be of material aid Little or no drainage material is inserted, a strip of rubber-dam may be used for twenty-four hours, seldom longer Immobilization should be kept up as long as there is any danger of muscular action disseminating the infection If any slough is present the instillation of Dakin's solution has in my hands been beneficial As soon as this stage has passed, however, active and passive movements should be encouraged at once, with the idea of assisting in the absorption of the excessive edema, as well as assisting in the prevention of tendon and joint adhesions I frequently begin these on the second day

The general considerations of treatment applicable to all cases are considered in the chapter on "The Principles of Treatment "

CHAPTER XXV.

RÉSUMÉ OF THE TREATMENT OF ACUTE SUPPURATIVE TENOSYNOVITIS AND MAJOR FASCIAL-SPACE ABSCESSES—PROGNOSIS.

RÉSUMÉ

SUCCESS in the treatment of tendon-sheath infections of the hand depends upon early accurate diagnosis, upon incisions so made as to drain the proper site without involving uninfected areas, and upon careful after-treatment

Two types must be recognized, the fulminating and the subacute. The treatment will vary with the type The most marked symptoms and signs are Localized excruciating tenderness over the course of the sheath, pain on extension, especially at the proximal end of the sheath, symmetrical enlargement of the entire finger, and the characteristic position of the finger

Infection from the tendon sheath of the index finger will most often extend to the lumbrical spaces and the thenar space and less often to the proximal interphalangeal joint, and the surface at the proximal end of the sheath

From the middle finger it most often extends to the lumbrical spaces and middle palmar space or at times to the thenar space and less often to the proximal interphalangeal joint, and the surface at the proximal end.

From the ring finger the extensions are the same except that they always involve the middle palmar space if extension takes place into the palm

From the little finger, the most common sites of extension are to the lumbrical space, the middle palmar space and the ulnar bursa, less commonly to the proximal

interphalangeal joint and the surface at the proximal end of the sheath. From the ulnar bursa it may extend to the radial bursa and the major forearm space and less often to the middle palmar space, interosseous space and the wrist-joint

From the sheath of the flexor pollicis longus infection spreads to the thenar space, ulnar bursa, and the deep forearm space and less often to wrist-joint

Incisions should be too radical rather than too conservative Incisions are best made in the fingers, upon one side of the tendon sheath over the length of the shaft of the middle and proximal phalanx, avoiding the joints, and into the proximal end of the sheaths or the lumbrical spaces to provide drainage there Exceptionally it may not be necessary to make this incision throughout its entire extent Complete splitting along one side should be done in case of doubt, since the adequacy of drainage should be the first requisite.

The ulnar bursal infection is best treated by splitting the sheath throughout its length in the palm, cutting upon the ulnar side The transverse carpal ligament may be cut if necessary This is commonly supplemented by an incision upon the ulnar side of the forearm above the wrist-joint, and on a level with the flexor surface of the bones, through-and-through drainage to the radial side may be carried out under the flexor profundus tendons If the pus has invaded the forearm, an ulnar incision is made at the middle of the forearm between the flexor carpi ulnaris and the flexor sublimis, or between the flexor carpi ulnaris and the ulna

Incision of the flexor pollicis longus sheath is made from a finger-breadth below the transverse carpal ligament to the distal end of the sheath If pus has extended to the forearm it will be found in the major forearm space and drainage should be instituted above the wrist by the lateral incision described under ulnar bursal infections

In the after-treatment the Bier constrictor may be used for a few hours, hot, moist dressings for two to four days, followed by dry dressings, the hand being held in the "position of function" with daily manipulation of joints and muscles after immediate danger of systemic infection has ended.

There may be accumulations of pus in any of the six fascial spaces in the hand I have described, to the exclusion of any or all the others, namely, the middle palmar, thenar, lumbrical, hypothenar, dorsal subaponeurotic, dorsal subcutaneous These may be involved separately or in conjunction with the tendon sheaths. Pus may also be found in the subcutaneous tissue on the flexor surface of the wrist and in the major forearm space The middle palmar space with its diverticula along the three lumbrical muscles is best drained by an incision along a lumbrical canal carried up to the space The thenar space is best drained by an incision on the dorsum to the radial side of the index metacarpal Hypothenar abscesses are localized and can be drained by simple incision All deep forearm extensions may be drained by lateral incisions above the wrist, the drainage being inserted under the tendons of the flexor profundus digitorum In neglected cases it may be necessary to make an added incision about the middle of the forearm on the ulnar side between the flexor carpi ulnaris and flexor sublimis digitorum

PROGNOSIS

The life of the individual is frequently jeoparized in either of these types of infections Undoubtedly if proper treatment is instituted the danger will be reduced to a minimum The lymphatic infections are the most frequent source of death The fulminating type of tendon-sheath infections may cause death, but the more chronic type, as also the fascial-space abscesses, should have few

fatalities except in neglected cases Especial caution should be exercised in giving a favorable prognosis in the aged, since the prognosis grows rapidly worse after forty. The presence of a nephritis is also of serious import.

It is very nearly impossible to state from a study of the literature what proportion of cases may hope for a satisfactory local outcome The authors base their statistics upon different classifications "Good result" is used by some to designate a recovery without loss of any part of the hand, with function at the wrist and in the uninvolved fingers, while others insist upon a com-



FIG 175 —Photograph of baby G 's hand and forearm three days after incision was made for the drainage of an ulnar bursal infection with extension into the forearm

plete restoration of the function in the finger as well. It is to be hoped that in the future the statistics may be more accurate. From my personal experience, however, I feel that the following statements may be made A complete functionating hand can always be promised in acute infections of the hand, not involving the tendon sheaths, unless necrosis of tissue has taken place or joint involvement has occurred That is to say, abscesses of the middle palmar space, thenar space, and forearm, as well as simpler conditions, can be treated with a perfect functionating result This has occurred in my experience



FIG 176 —Result three months after (baby G), showing extension and flexion of fingers Perfect function restored except for two distal phalanges of the little finger

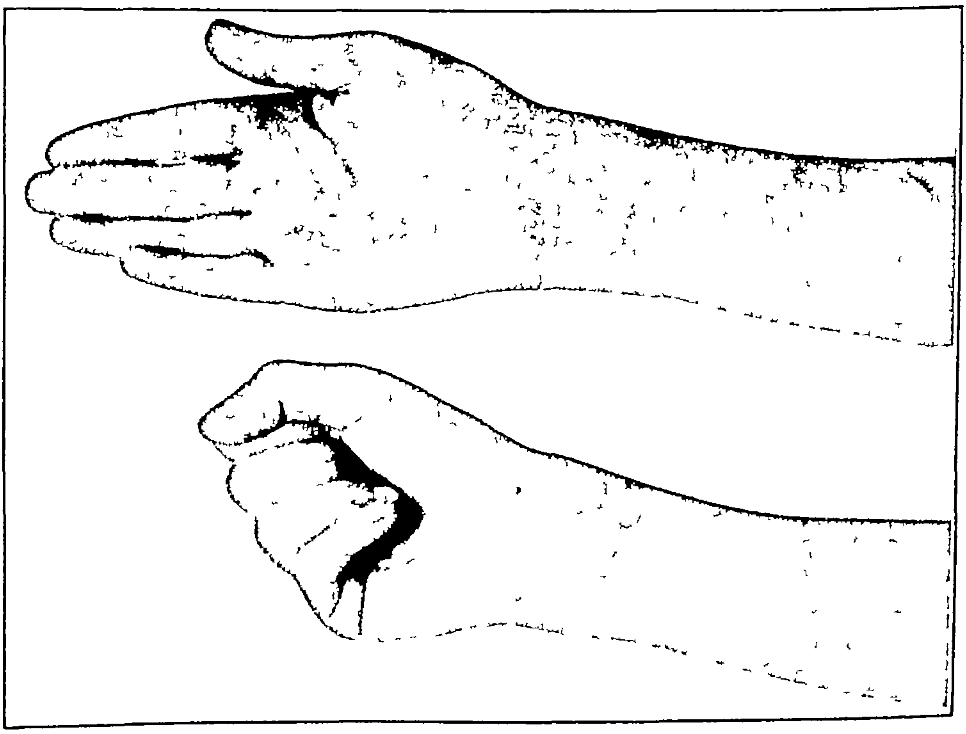


FIG 177 —Same hand showing the result at the age of thirteen years

even after four or five weeks of inadequate treatment In tendon-sheath infection, however, the results are not nearly so good By proper and early treatment a perfect result can generally be assured as to function of the wrist-joint, hand and fingers not involved. Where the tendon sheath of a finger is involved, unless early treatment is instituted, flexion of the phalanges of that finger is likely to be lost, while flexion at the metacarpo-phalangeal articulation is generally preserved In early cases or under exceptional circumstances complete function may be secured

In this connection it is interesting to note the result obtained in a child three months of age who had a suppurative ulnar bursitis with extension into the deep forearm space He was so ill as to arouse anxiety as to his life The various incisions described as applicable to such an infection were made The child was discharged from the hospital on the eighth day The illustrations present the patients arm at the time of operation, three months later, and finally after thirteen years (Figs 175, 176, and 177)

In the thumb, even though the function of the flexor pollicis longus is lost, the hand will not be seriously impaired, since the smaller muscles of the thumb will give it such function that the impairment will not be as serious by any means as in the fingers Extension from tendon sheaths to the forearm, if treated early before destruction of tissue has ensued, should not impair the result but, if serious complications or sequelæ are present, the patient must be warned that the course may be long and the ultimate restoration of function depend much upon continued and faithful application of after-treatment

PART IV.

Complications, Sequelæ and After-treatment of Infections of the Hand.

CHAPTER XXVI

COMPLICATIONS OF INFECTIONS OF THE HAND

CHRONIC PROCESSES, OSTEOMYELITIS, ARTHRITIS

IN cases showing a long-continued suppuration, we ask ourselves what structures are involved which prolonged the trouble, or why we have inefficient drainage Frequently both factors are at work By far the most frequent causes are necrosis of tendons, osteomyelitis and arthritis

Areas which were primarily poorly drained cavities are soon complicated by one of these factors Suppurative arthritis seldom exists without concomitant osteomyelitis Such cases frequently give a history of primary tenosynovitis, followed by osteomyelitis, ending in arthritis

The pathology of these cases naturally varies with the tendency of the tissues to react to the particular germ which is the exciting cause, the length of time the process has existed, and the structure involved. Grossly the most important findings are the sinuses, which are an almost constant accompaniment of chronic

disease Here we note several types, and while there is a distinct difference between them, any system of classification is inadequate We might say the osseous and connective-tissue types, or the acute, subacute and chronic While the pathology presents some justification for either system, yet the reactive resistance of the individual and the kind of germ enter into the subject as varying factors, consequently only generalized statements can be made

The chronic osseous type presents three pictures, varying with the bones involved (1) Those cases where the terminal phalanx is the seat of osseous destruction, (2) where the finger proper is involved, (3) where the metacarpal and carpal bones are involved

INVOLVEMENT OF THE FINGER PROPER

While sinuses from necrotic tendons uncomplicated by osteomyelitis may appear at any site, the common location particularly in the index, middle, and ring fingers is at the proximal end of the sheath in the distal portion of the palm

Those cases (first group) showing chronic osseous processes in the terminal phalanx have already been discussed in the chapter on Felons (Chapter X)

The second group noted in the chronic osseous type is that which comprises suppurative processes of the proximal and middle phalanges We all have had opportunity to observe that the proximal interphalangeal joint particularly may become involved early, either primarily or secondarily In the case of the metacarpo-phalangeal joint, however, there is more fibrous tissue intervening between the tendon sheath and the joint and the adjoining bone; therefore the sheath erodes through at some less resistant point, as, for instance, at the proximal interphalangeal joint, in the course of the tendon over the proximal phalanx, or at its proximal end in the palm of

the hand Frequently I have seen a sinus lead from the proximal end of the sheath of a tendon through the palmar fascia, and the metacarpo-phalangeal joint still remain intact (Fig 178) Again, the metacarpo-phalangeal joint is likely to escape in cases of palmar abscesses where the diaphysis of the metacarpal has become involved, or even when the process has been so severe as to extend under the transverse carpal ligament and invade the carpal articulation Its primary involvement in knuckle injuries from blows on the teeth in fights is



Fig 178 —In this case the metacarpo-phalangeal joint was intact, although the tendon sheath was involved and a sinus had opened at its proximal end through the palmar fascia, all of the distal and part of the middle phalanx had been lost and the proximal interphalangeal joint was extensively destroyed

discussed in the chapter on Metacarpo-phalangeal Infections It has been my experience in these cases that the distal articulation frequently escapes even in long-continued synovial disease and extensive osteomyelitis

Ordinarily chronic suppuration in the finger is a result of either a sloughing tendon or an involvement of the proximal interphalangeal joint, and the pathological condition noted in Fig 179 is fairly typical The constant irritating discharge coming from the necrosing bone, passing through the connective tissue rich in lymphatics,

produces an excessive deposit of granulation tissue, building up a small volcano-like structure, from which oozes forth a constant stream of pus, and through which winds a tortuous canal leading down to the necrotic bone. Where bone alone is involved, I have seen this crater clearly defined, occupying no greater extent than the length of one phalanx and raised above the surface for a distance half the diameter of the finger. This characteris-

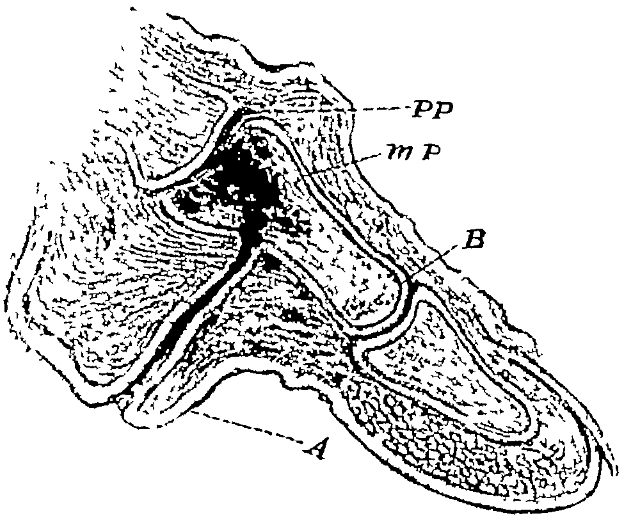


FIG 179 —Drawing from pathological section, showing sinus leading down to carious bone An associated tenosynovitis has increased the extent of the granulation tissue and destroyed in part the typical volcano-like picture of an uncomplicated palmar bone sinus *A*, ostium, *B*, intact bone, *MP*, middle phalanx, *PP*, proximal phalanx

tic picture, however, is seldom seen, owing to the very frequent involvement of the tendon or the joint in the same process Here, while the development of granulation tissue is still excessive, the mouth of the crater is generally much wider, owing to the excessive discharge from the tendon sheath The granulation tissue is not so circumscribed, although very abundant. Moreover, the picture is somewhat less graphic, owing to the associated swelling of the finger along the tendon sheath, the absence

of which in the first case serves to accentuate the local tumor formation. Again, if the sinus be upon the dorsum there is less granulation formation, owing both to the smaller amount of connective tissue and probably also to the great reduction in the number of lymphatics (Fig. 180).

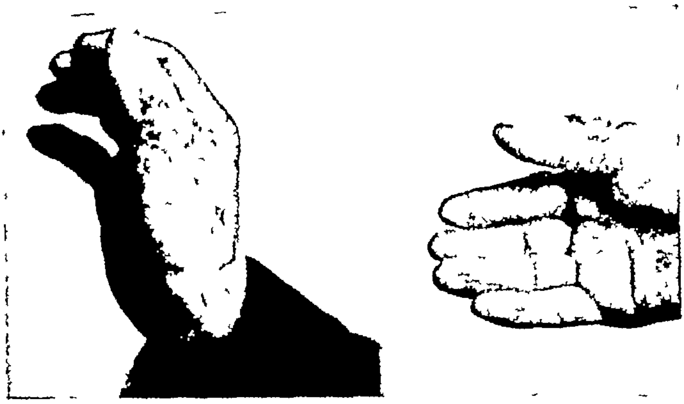


FIG 180 —Uncomplicated bone sinus on dorsum of phalanx

It is not necessary to go into the minute pathology of osseous necrosis, since that process is well known and described in the ordinary text-books However, a few details peculiar to these two phalanges should be mentioned. We so often see three processes in conjunction that it is difficult to say in what sequence they developed—namely, tenosynovitis, arthritis of the proximal interphalangeal joint, and necrosis of the middle phalanx The cross-sections here presented demonstrate the close proximity of the tendon sheath to the bone and joint respectively (Figs 181 and 182) From the character of the tissue it would seem reasonable to assume that the joint is first involved, and the phalanx sequentially. In the few early cases that I have been able to observe discriminatingly, the joint seemed to have the more extensive involvement of the two. However, if that be true, why does the middle phalanx suffer so much more than the proximal one, a fact which I have had the opportunity to verify frequently Is it that the point of invasion is the

epiphysis of the middle phalanx? Does the fact that this phalanx only has an epiphysis articulating with the joint have any bearing on the subject? This question must be left for further study

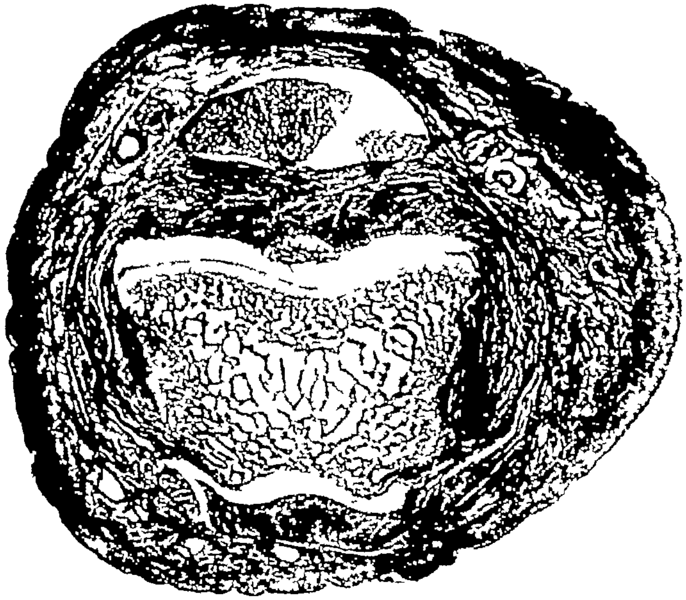


FIG 181 —Cross-section through the metacarpo-phalangeal joint, showing head of the proximal phalanx Notice the large amount of tissue between the tendon and the joint cavity as compared to Fig 182

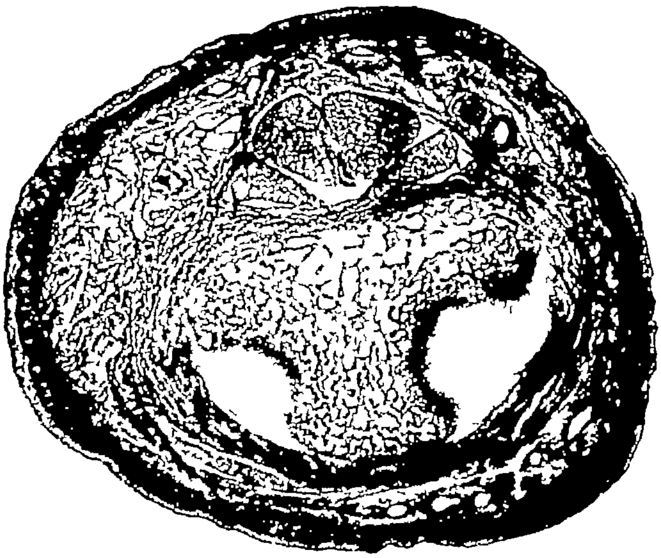


FIG 182 —Cross-section through the epiphysis of the middle phalanx Notice the loose mesh and the small amount of connective tissue between the tendon and the bone

Again, destruction of the epiphysis is frequently noted, while the diaphysis is only partly involved (Fig. 179). The anatomical relation of the sheath of the tendon to the joint capsule and the epiphysis may help to explain this, but it is probable that the vascular nature of the epiphyseal tissue may have considerable bearing, since the involvement may have its origin through the blood supply rather than by direct erosion That isolated destruction of a diaphysis of a phalanx may occur at times cannot be questioned, and a study of the cross-sections demonstrates how easily this can occur if the tendon sheath be eroded.

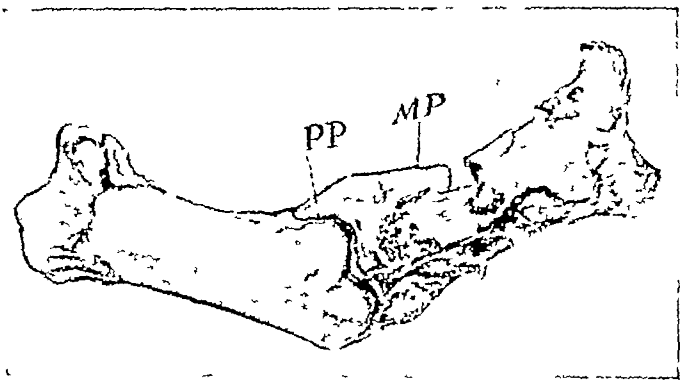


FIG 183 —Drawing from a pathological specimen, showing destruction of the epiphysis of the middle phalanx, with pin-head-sized areas of the necrosis on the head of the proximal phalanx *MP*, middle phalanx, *PP*, proximal phalanx

What we most often find upon operation in these cases is a suppurative arthritis with extensive destruction of both the epiphysis and shaft of the middle phalanx, while the proximal surface of the joint, that is, the head of the proximal phalanx, may be only slightly or not at all eroded (Fig 183), at least, the articular surface is still clear and shining, with possibly one or two minute foci of destruction Frequently it has shown a larger area of necrosis upon the shaft just at the point where the ligaments of the joint are attached Indeed, at times, either upon the volar or dorsal surface, varying with the site of the original infection, I have scooped out at this site an

area the size of a small pea, the articular surface apparently being free, while the epiphysis of the middle phalanx was almost entirely destroyed.

TREATMENT —In the chronic processes involving the finger proper, the diagnosis must be made first as to the structure involved If the tendon sheath, it must be opened throughout its extent to give perfect drainage Generally it will be necessary to remove the tendon in these chronic cases The possibility of localized involvement must always be borne in mind In these cases a plastic exudate forms and prevents extension along a sheath, here only so much of the sheath as has been involved should be exposed If the proximal interphalangeal joint be invaded, some judgment is called for, since in the very earliest stages it may recover with partial restoration of function if the infection is a mild one, the joint surfaces not destroyed, and other structures which might prolong the suppuration are uninvolved In a great majority of the cases, however, considerable destruction of the proximal end of the middle phalanx will have taken place when the case comes to operation, and the question arises whether an amputation should be advised Certain sociological factors come into consideration If the patient be a laboring man, with a family dependent upon him, and at examination we find an extensive destruction of the joint with a tenosynovitis, amputation offers the quickest method of giving a serviceable hand If, however, the patient desires to preserve the finger, in a majority of the cases one can be assured that the finger may be preserved, but that it will be somewhat shortened and probably have no function except at the metacarpo-phalangeal joint. If the tendon is involved with the osteomyelitis no attempt is made to secure a movable joint After removing the necrotic tendon and bone the finger is immobilized in slight flexion of all the phalanges so that it will not be disabling because

of its extended position in a straight line. After recovery the finger, which can generally be moved at the meta-carpo-phalangeal joint, will, in this flexed position, have some function and present a better cosmetic appearance. In certain cases it becomes imperative to make the attempt, as, for instance, in infections of the thumb. This member is so valuable that some sacrifice is justifiable in the attempt to preserve it In Case XXVI, quoted below, the articular surfaces and a considerable portion of the shaft of the proximal phalanx were removed There was no involvement of the tendon sheath A fairly serviceable opposing member was saved to the hand

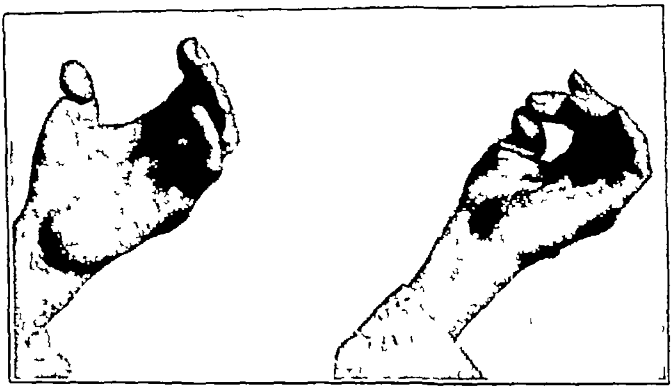


FIG 184 —Photograph showing thumb in which joint has been resected Notice the opposing ability of the member (Case XXVI)

CASE XXVI —Primary paronychia of thumb, secondary suppurative arthritis of interphalangeal joint, resection, ultimate recovery, with preservation of the thumb

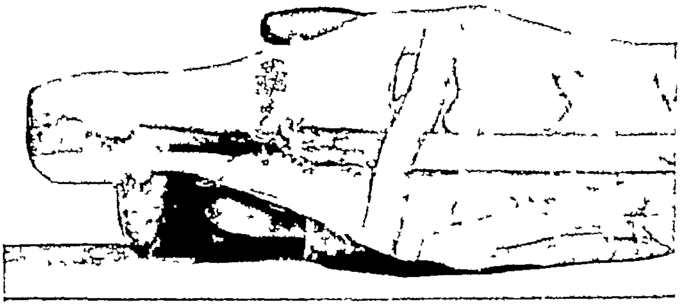
C H, treated in the Northwestern University Medical School Dispensary Infection began on the thumb under the nail at the side and developed into a typical "run around" When he applied at the dispensary, four weeks after the beginning of the infection, a chronic suppurative arthritis had developed, involving the interphalangeal joint Under narcosis the epiphysis of the distal phalanx and about half of the distal portion of the proximal phalanx were found partially destroyed All this involved bone was removed with a curette, the nail was removed, silkworm-gut drain inserted, hot boric dressings applied The tendon sheath of the flexor pollicis longus was not involved The patient returned repeatedly for dressings, and after four weeks all discharge ceased The patient was

discharged with the thumb shortened ½ inch, with ability to flex the distal phalanx 20 degrees, complete function in the metacarpo-phalangeal joint There was little strength to the flexion of the distal phalanx, but it served admirably as an opposing member when using the fingers (Fig 184)

FIG 185



FIG 186



FIGS 185 and 186 —Photographs of a finger with a chronic suppurative arthritis of the proximal interphalangeal joint, dressed in extension produced by an ordinary rubber band or extension spring attached to the end of the finger by narrow adhesive strips Extension is secured by fastening the rubber band on the back by a piece of adhesive plaster, as shown in Fig 186, or by attaching a spring to the end of the splint The splint on the palmar surface is prevented from being displaced up the arm or laterally by adhesive strips as shown in the figures It is a modified Buck's extension The relief from discomfort and rapid recovery under its use is often remarkable

If we attempt to save the finger in the cases of osteo-myelitis and arthritis the procedure is as follows. Owing to the frequent destruction of the proximal end of the middle phalanx, this is chosen for attack, and the entire epiphysis and generally about half of the shaft is removed If the articular surface of the proximal phalanx is intact, it is not disturbed, otherwise this may be removed also,

my desire being in the first place to remove all necrotic bone, and secondly, to separate the ends of the bone so far that only a fibrous union will take place, thus allowing some motion at this joint if the tendon is intact In such cases I have tried, with moderate success, a variety of extension on a straight splint The proximal end is fastened at the wrist, and at the distal end, adhesive straps are fastened to the end of the splint and the distal portion of the finger with either rubber or spring extension between, so that the ends of the necrotic bones are separated The details of this simple mechanical contrivance may be seen by examining Figs 185 and 186 Other more complicated types of extension have been used, but with little more success The splint should be removed each day and active and passive motion used diligently Not much can be promised in the way of function in a majority of cases That in exceptional cases these fingers can be saved with a moderate amount of function, even in some cases of combined suppurative arthritis and tenosynovitis, is demonstrated by the following case

CASE XXVII —Limited tenosynovitis of index finger, arthritis of proximal interphalangeal joint, osteomyelitis of middle phalanx, resection of phalanx, recovery, with preservation of the finger and slight motion at the joint

Miss C W Seen in consultation with Dr C E Boddiger Infection had begun in the index finger by a prick of a needle while sewing two weeks previously, and the soft parts had been opened over the middle phalanx

Condition upon Examination —Suppurative tenosynovitis of the index tendon extending to the level of the metacarpo-phalangeal articulation, but no farther Tendon exposed Suppurative arthritis of the proximal interphalangeal joint with destruction of the proximal end of the middle phalanx Proximal phalanx not involved, articular surface slightly clouded, but not eroded

Operation —Tendon sheath opened throughout extent of infected area Middle phalanx resected to one-half its extent Dorsal counter-incision made at side for thorough drainage, and hot boric dressings applied

Course —After three weeks the finger had entirely healed, flexion at metacarpo-phalangeal and distal phalangeal joints perfect, flexion at proximal interphalangeal joint 15 degrees Six months after operation atrophy of soft tissues of distal and middle phalanges The patient states that the finger is not of great service, but, on the other hand, is not in the way, and she is very glad, for cosmetic reasons, that it was saved

Where there is only a destruction of the synovial covering of the joint, resection is not indicated A functioning joint can be restored in case of ankylosis if the tendon sheath is not involved If the destruction of the adhesions by repeated flexion of the finger by passive motion, supplemented by active motion with the help of various appliances described in a subsequent chapter, which I have used with more or less succes at various times, does not succeed, the implantation of adjacent connective-tissue flaps or living attached tags of cartilage is to be recommended or, if these cannot be secured, the transplantation of a pad of tissue and fat from a distant part of the body may be used with some assurance of success

Suppuration is uncommon in the metacarpo-phalangeal joint, but here also resection may be resorted to if the tendon is intact If this complication be present associated with a suppurative tenosynovitis amputation of the finger is generally advisable

INVOLVEMENT OF THE HAND PROPER AND THE METACARPALS AND CARPALS

Pathology —The suppuration extending from necrotic tendons of the thumb and little finger with the associated buræ is diffused under the fascial sheath In these chronic cases an involvement of the bones of the hand or arthritis at the wrist-joint will be found frequently In this third type of osseous lesion in which the metacarpals are involved, the dense aponeurosis upon the palmar side and the sheet of dense tissue upon the dorsum uniting

the tendons of the extensor digitorum communis prevent the free egress of pus, and as a consequence, it is more likely to burrow a considerable distance from the site of origin before exit (Fig 188) This diffuses the reactive inflammation, and even if the exit is found near the site, the dense sheet prevents the crater-like elevation of granulation tissue noted in the second or phalangeal

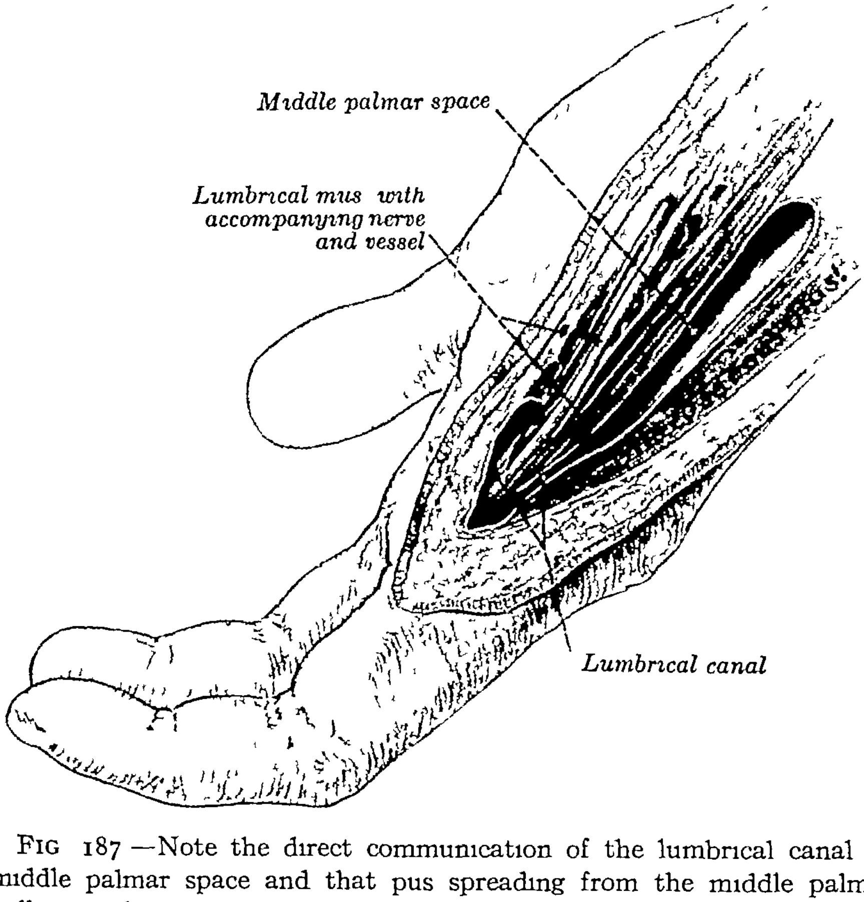


FIG 187 —Note the direct communication of the lumbrical canal with the middle palmar space and that pus spreading from the middle palmar space will pass along the lumbrical canal into the lax connective tissue of the web

type Hence, we are more likely to find a diffuse swelling of the whole palm or dorsum with multiple ostia on the dorsum, any of which may be open for a time and discharge, while another may be closed There is often only a small amount of granulation tissue about the openings In these cases of early osseous involvement often no sinus will appear upon the palmar surface, unless

the soft tissues of the palm have been seriously involved primarily, or the infection has spread into the wrist-joint, and this generally preceded by palmar phlegmon or tenosynovitis. In these cases the sinuses tend to dis-

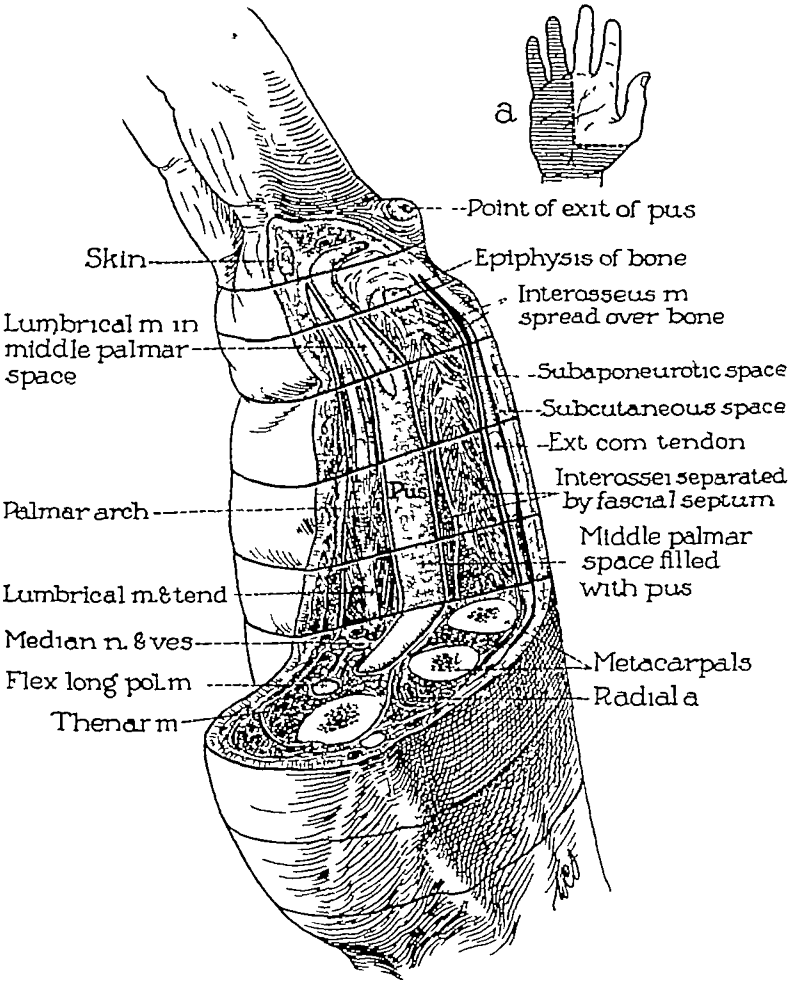


FIG 188 —Drawing showing the relation of pus in the middle palmar space to the tendons Also showing course pus pursues in its course along the lumbrical muscle to point on the dorsum near the web Serial sections of the hand were made as shown, the tissues teased out and middle palmar space filled with plaster of Paris Sections restored to normal position and sagittal section made between ring and middle metacarpal of all sections except the proximal

charge near the wrist The ostia on the dorsum appear at any point, but have a predilection for the sides and distal part near the knuckles (Fig 189), owing to the dense sheet of tissue before mentioned It is a well-known fact, however, that frequently this sheet has areas where it is

not complete, particularly in the lower third between the tendons, and through these pus may discharge But

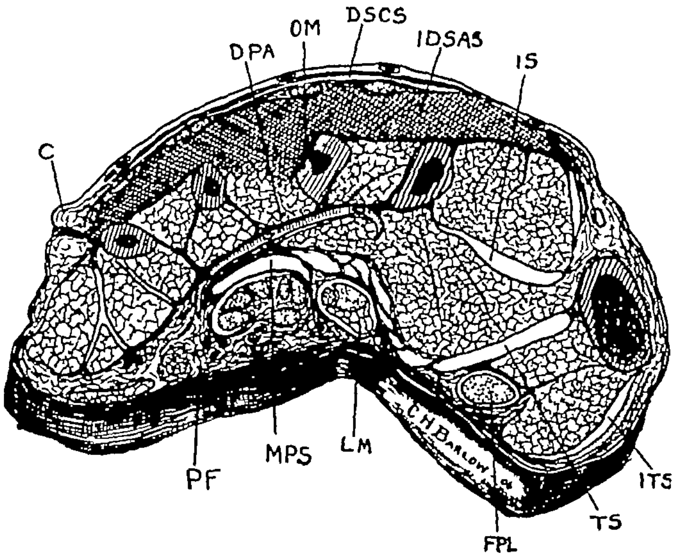


FIG 189 —Schematic drawing, showing pus under dorsal aponeurosis with ostium at the side *C*, site of discharge of pus, *DPA*, deep palmar arch, *DSCS*, dorsal subcutaneous space, *FPL*, flexor pollicis longus, *IDSAS*, infected dorsal subaponeurotic space, *IS*, indefinite space, *ITS*, indefinite thenar space, *LM*, lumbrical muscle, *MPS*, middle palmar space, *OM*, osteitis of the metacarpal, *PF*, palmar fascia, *TS*, thenar space

it is not at all an uncommon thing to see a sinus ostium at either side over the index and little finger metacarpal,

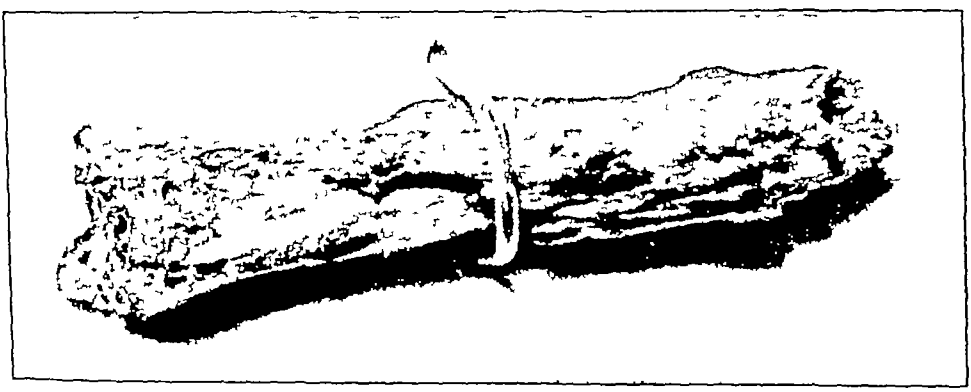


FIG 190 —Metacarpal removed from hand of patient who suffered an osteomyelitis following a severe tonsillitis

and one or two at the distal end between the knuckles, from a single focus of infection in either the middle or

ring metacarpal (Fig 114), as will be shown clearly by roentgen-ray picture. Again these ostia on the dorsum at the knuckles may be due to a chronic process in the palm discharging through the lumbrical canals (Fig 188)

So far as I have observed, there is no peculiar pathological destruction of the metacarpal bones in these cases (Fig 190). There is one clinical fact, however, worth remembering from a therapeutic standpoint, and that is the relative immunity from involvement of the metacarpo-phalangeal joint, this is possibly owing to the dense ligaments surrounding the joint, which protect it from invasion by way of the synovial sheath and adjacent phlegmons As a consequence of this we are often able to preserve a functionating finger, although a considerable destruction of the metacarpal may be present; isolated inflammation of a metacarpal is uncommon except in tuberculosis or syphilis It should be noted that we may see isolated osteomyelitis as a part of a systemic infection, comparable to the osteomyelitis seen in other bones of the body, as the femur A photograph of such an osteomyelitic destruction is herewith presented The patient had suffered from a severe tonsillitis and developed tenderness on the dorsum of the hand over the junction of the epiphysis and the diaphysis of the ring finger metacarpal. At the operation the entire diaphysis of this bone was removed subperiosteally, care being taken to save the epiphyses to prevent sequential involvement of the joints (Fig 190) In five patients I have removed the four finger metacarpals and had regeneration of bone with satisfactory function

The following history of a patient in the practice of Dr. H. B Baumgarth, with whom I saw the case in consultation, illustrates the course of these chronic cases when untreated

Case XXVIII —Mrs G received infection September 5, at web between the middle and ring fingers The patient consulted a mag-

netic healer and remained under his care for seven weeks, when she applied to Dr Baumgarth, who obtained the following history and drained the hand properly Twenty-one days after the receipt of the infection, point 2, noticed on the dorsum, opened up, a few days later, points 3 and 4 opened, slightly more on the dorsal surface than on the palmar Points 5, 6, 7 and 8 appeared successively in the next few days After an interval of a few days, points 9 and 10 appeared followed in succession by 12 and 13, and after an interval of several days, 14, 15 and 16, at which time the patient applied to Dr Baumgarth, who thoroughly drained the pockets, and the patient made a tardy recovery The atrophy of the distal phalanx of the index finger is due to a previous felon The atrophy of the other fingers followed as a sequence of the present infection

On February 25 adhesions were broken up under nitrous oxide, which benefited the movement of the finger and wrist to a slight extent only



FIG 191 —Photograph of Case XXVIII Figure numbers on the photograph represent the various sinuses and their approximate order of development by which the course of the infection can be traced

A careful study of this case serves to point out the pathological sequence which occurred as a result of the infection (Fig 191) Points 1 and 2 were the original

site of the infection, which spread from there, without doubt by lymphatic extension or continuity of tissue, along the lumbrical canal into the mid-palmar space, from here in turn it retraced its course through the lumbrical canals to the base of the index finger, point 4, and the base of the little finger, point 6 The ulnar bursa evidently became involved, and points 9 and 10 show the site of rupture from the sheath, the other areas at the base of the palm developing as a rupture of the



FIG 192 —Photograph showing claw-hand in neglected tendon-sheath infection

proximal end of this bursa This point was corroborated by Dr Baumgarth at the time of operation, since pus was found above the transverse carpal ligament in this synovial sac It is to be noted that all the primary points of rupture from 1 to 8 appeared upon the dorsal surface of the base of the webs of the fingers Points 12 to 16 came from suppurative arthritis of the wrist-joint

The characteristic claw-hand seen in neglected tendon-sheath infection is shown in Fig 192.

In those exceptional cases in which the pus has extended to the dorsum between the metacarpal bones, there is

generally some destruction of bone, requiring attention. It is at times seen in advanced cases accompanying wrist-joint invasion.

TREATMENT OF CASES INVOLVING THE HAND PROPER.—The treatment in those patients in whom the chronic process lies in the palm may be confusing. We should determine first the location of the pus Does it lie in the synovial sheaths or in the fascial space? Are the bones or the wrist-joint involved? While theoretically difficult to determine, it is not so confusing as in the acute cases, since there are generally sinuses which can be followed down to the hidden pockets Roentgen-ray photographs may show necrotic bone. Complete anesthesia is essential No operation upon infected hands should be undertaken without it. The ramifications should be followed up carefully and with patience I shall not speak in detail of the factors which lead us to diagnosticate the presence of pus in the various sites, since this has already been discussed exhaustively in the previous chapters

Various sinuses leading from the tendons to the surface will be followed down to the respective synovial sheaths. The sinuses found at the most proximal point of the finger sheaths designate the corresponding sheath, and this should be cut down upon and followed distally along the finger until every part of the tendon bathed in pus is exposed Where the little finger tendon is involved, the extension of the sheath in the palm should be borne in mind, and the opening continued proximally over this when the grooved director inserted into the infected sheath on the little finger passes up into this without obstruction Here the sheath should be opened throughout its extent up to the transverse carpal ligament, the incision lying to the ulnar side of the tendons. The incision should end at the transverse carpal ligament until the decision has been made as to whether the infection has extended under this into the proximal end of the sheath

above the transverse carpal ligament If this is diagnosticated it will be found more satisfactory to drain the upper end of the sheath by incisions upon the ulnar side of the forearm as described in the chapter dealing with ulnar bursitis, rather than by cutting the transverse carpal ligament It is not wise to open the sheath on the volar surface above and below the ligament and leave this latter intact Having thoroughly opened this bursa, the question then arises Has the radial bursa, *i e*, the sheath of the flexor pollicis longus, become involved? If so, this must be opened throughout its extent up to a

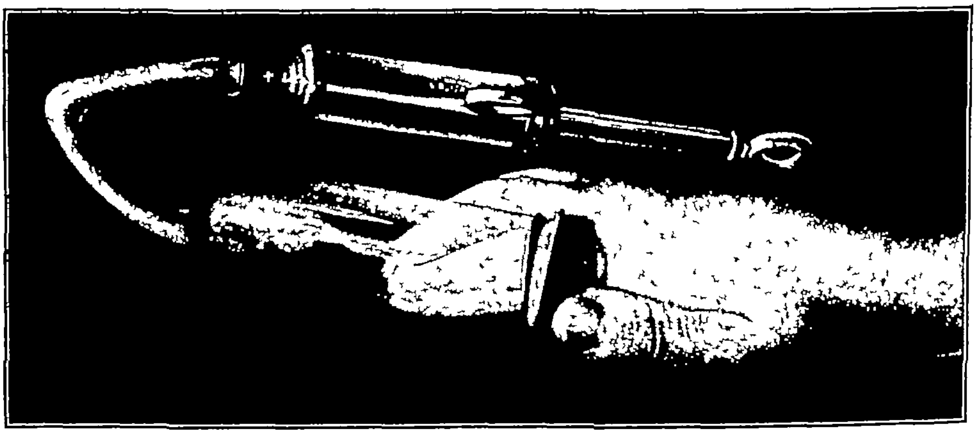


FIG 193 —Showing Klapp's aspiration cup used in some old, chronic infections of the fingers

thumb's breadth distal to the transverse carpal ligament. The incision should stop here for fear of injuring the motor nerve to the thenar area

If the tendons have become fragmented or necrotic, their removal is indicated Some of the chronic, sluggish processes in the fingers have seemed to be benefited by the Klapp suction cup (Fig 193)

If the fascial spaces are involved, they should be drained after the methods described in Chapter XXIV

In considering the treatment of those cases in which the suppurating ostia appear upon the dorsum, particularly between the knuckles, I have already pointed out

that in a majority of cases these are really sinuses leading from the palm along the lumbrical canals (Fig 188), and the perfect drainage of the palm along the lumbrical canals, as already mentioned, will end in rapid recovery if uncomplicated by tendon or bone involvement

If the bones of the hand or wrist are involved, they should be removed or the necrotic part curretted out. Regeneration of the metacarpals after subperiosteal resection is the rule

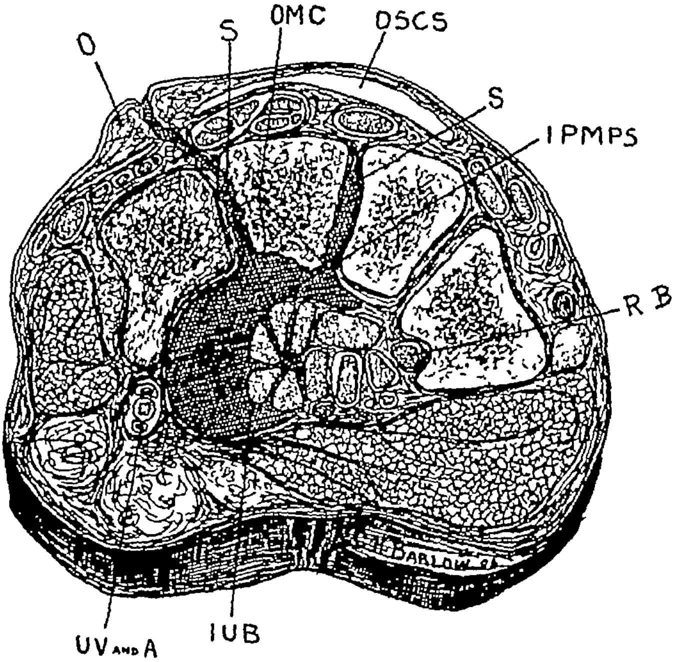


FIG 194 —Drawing showing intimate relation of the ulnar bursa to the os capitatum and its early involvement Notice the association of the radial bursa and the multangulum majus *DSCS*, dorsal subcutaneous space, *IPMPS*, infected process leading from middle palmar space, *IUB*, infected ulnar bursa, *O*, ostium, *OC*, os capitatum, *R B*, radial bursa, *S*, sinus, *UV and A*, ulnar vein and artery

WRIST-JOINT INFECTION

If infections are treated promptly involvement of the wrist-joint is uncommon. In certain cases, however, it will be met with either early in the course or later as a complication The wrist-joint involvement is a most serious complication, and it should be watched for, particularly in aged patients with involvement of the

radial bursa (tendon sheath of the flexor pollicis longus) One cannot help but feel that the history of a previous radial bursal infection is more than a coincidence, as yet, however, no definite anatomical reason can be adduced to explain it. I would hesitate to say that in a large series of cases we would find the infection of the wrist to follow involvement of the radial bursa more often than that of the ulnar bursa In fact the latter source is suggested by the frequent observation of early involvement of the os capitatum In none of my injections of this synovial sheath has the mass ruptured or extended into the wrist-joint

EXAMINATION OF THE RADIAL BURSA IN CADAVERS —To determine whether or not there is at times a normal opening connecting the radial bursa and the wrist-joint, with the assistance of Prof P T Burns and Dr A T Horn, of the Anatomical Department of the Northwestern University Medical College, I have examined 30 cadavers, and in not one of them have we found any normal opening, although Professor Burns states that he has at times noted such a communication This is borne out by other observers, but it must be extremely rare According to Schwartz, the parietal layer of the ulnar bursa is attached to the ligaments and periosteum of the carpal bones, particularly the hamate and os capitatum

PATHOLOGY FOUND IN SERIOUS WRIST-JOINT INVOLVEMENT —Since all of my personal cases have recovered, I have been compelled to turn to the literature for reports of postmortems

In the case reported below the position of the sinus openings on either side above the transverse carpal ligament at the site of the two vessels emphasizes the tendency of abscesses on the forearm to follow the vessels (see Experiment 47, where the only place the mass became subcutaneous was on the ulnar side just above the transverse carpal ligament). The absence of tenderness and pain about the necrotic joint is also worthy of note The involvement of the radio-ulnar joint, as here noted, is a frequent complication.

Case XXIX (Bauchet).—Deep phlegmon of the right thumb, deep phlegmon of the hand, phlegmon of the forearm, fistulous processes, abundant suppuration. Great scar over the sacrum, septic infection. Death. Postmortem.

This man, between fifty-five and sixty years of age, gives a history of inflammation of the thumb two months before entrance. On the forearm there are two openings, one is at the inside and the other at the outside of the anterior surface, both are about 4 cm. from the radio-carpal joint. These two openings are longitudinal, about 2 cm. long, with edges grayish and fungous. At the level of the first phalanx of the thumb one sees the scar of a former purulent focus. No redness, dorsal aspect of the hand shows no tumefaction, no sinuses. Tenderness to pressure is not very acute, the wrist is neither swollen nor painful. By pressing on the palm of the hand or on the lower part of the forearm, one causes a notable quantity of whitish, poorly mixed, fluid pus, without a bad odor, to flow out through the openings already mentioned. The probe introduced through these openings slides a considerable distance along the lower layers of the forearm, but meets no denuded portions of the bone.

Aside from the two openings already mentioned, one notes still farther inward, at the level of the upper-third of the anterior surface, a small opening from which pus escapes, but in smaller quantity than from the other two openings.

By pressing the ulna, the radius, and at the same time trying to make the patient move the wrist, one notes a grating between the ulna and the radius and between these bones and those of the wrist, which resembles nothing more than two nuts being rubbed together.

Diagnosis.—Deep whitlow of the thumb, extension of inflammation into the great common synovial sheath of the tendon of the little finger, rupture of the focus between the muscular layers of the forearm, but more especially of the deeper part, extension of the suppuration to the carpal joints, necrosis of the bones.

Postmortem.—The tendons are fixed in an invariable position, and to free them it is necessary to cut out the resisting fibrous adhesions. These changes are evident in the palm of the hand, under the transverse carpal ligament, and the lower part of the forearm, all along the synovial sac. These changes extend to the ends of the tendons of the thumb and little finger. They stop slightly above the metacarpo-phalangeal joints of the index, middle, and ring fingers. Along these fingers the synovial sheaths and the tendons are absolutely intact. The large focus, black and purulent, has an exit in the two openings before mentioned. At the upper and outer part it is closed, and the muscles of the forearm on this side are healthy. On the ulnar side, on the contrary, the fibrosynovial sac is frayed, and the pus has spread to the level of the upper part of the forearm, between the deep and superficial muscular layers. This purulent focus, formed

by rupture of the synovial sheath, has its exit in the smaller opening, which has already come under discussion

The joints, radio-carpal, radio-ulnar, and carpal, are open anteriorly and communicate extensively with the palmar purulent focus, through several openings The bones are neither red nor spotted nor crumbling. They are rather of an ivory-gray color and, in spots, blackish, there is no false membrane or generative abscess in the joint, but the cartilage has been destroyed, almost entirely resorbed, and has disappeared, the bones bared of this cartilage resemble bones which have been soaked in water for some time

In the following case the decreased sensitiveness in the area of the distribution of the median nerve serves to emphasize the tendency of infection to spread along that nerve, as demonstrated in Experiment 47 and shown in Fig. 143

CASE XXX (Forssell) —Tenosynovitis of the thumb, little finger, and ulnar bursæ Phlegmon of the forearm and articulation between hand and forearm

S T, aged thirty-three years, female April 4, 1898 Distinct symptoms of suppuration of the carpal tendon sheaths (tendon sheath of the little finger intact) and on the forearm Only slight pain on passive movements of the finger, "the finger twinges," the same is true of palpation of the palm and the flexor side of the forearm Complete opening of the ulnar bursa, by mistake the sheath of the little finger was opened, no pus, incision into the thumb, pus within and without the sheath

April 11 Incision into the lower part of the forearm down to the ulna (burrowing of pus) For three days there have been symptoms of infection of the wrist-joint, pus pours from a small hole in the capsule between the pisiform and triquetrum Around the tendon of the flexor pollicis longus there is much pus, wherefore an incision of the same is made, it was especially necrotic in the region of the carpal ligament, here there is also necrosis of other tendons

April 12 Much pus in the wrist and upper arm Several carpal bones removed under anesthetic

April 16 Temperature, 102° to 105° F Amputation of the arm Examination of the amputated arm, elbow-joint intact, all pus cavities opened except the suppurated tendon sheaths of the fourth and third fingers Necrosis of all tendons at the tranverse carpal ligament, the condition of the median nerve was by mistake not investigated

April 17 Exitus 12 M

Epicrisis —Worthy of notice was the decreased sensitiveness and pain in the median region, due probably to the compression of the nerve The inflammation of the wrist was possibly due to the infection of the joint between the pisiform and the triquetrum, in the capsule of this joint a certain defect was noted, whether primary or secondary, still pointing to a certain weakness in the boundary of the canal toward the carpal canal

In the subjoined case the wrist did not become involved until fifteen days after the beginning of the infection when the case was seen in consultation In this case, as in others reported here, there may be some question as to whether or not the incisions were made early enough and at the proper sites Throughout the literature it is evident that surgeons have paid too little attention to the fascial pockets in which pus lies, confining their attention almost entirely to the tendon sheaths.

Case XXXI —Compound dislocation of thumb Infection of radial and ulnar bursæ, resection of necrotic carpal bones

C E, aged fifty-eight years A large quantity of grayish-yellow, thin fluid pus was freed by opening the radial bursa An incision which had been made on the volar side of the thumb lengthened, and the tendon removed

May 20 Complete splitting of the ulnar bursa and the tendon sheath of the little finger, in the bursa and the tendon sheath a yellowish fluid pus No burrowing toward the forearm could be discovered The swelling on the hand went down On May 24 it is especially noted that there is no swelling around the wrist-joint The superficial tendons of the little finger had become necrotic just below the carpal ligament, and those of the fourth finger as well showed beginning of necrosis here

May 29 Temperature, 37 3° to 37 4° C Slight pain in the hand near the wound in the carpal region Several tendons showed signs of necrosis On the anterior side of the wrist, exposed bone (radius, carpal bone?) can be felt

June 7 Temperature, 37 4° to 38 2° C Partial resection of the wrist-joint Removal of the carpal bones except the multangulum majus and pisiform, hamate necrotic

By these cases I have attempted to portray the pathology, symptomatology, and course of these forearm cases, complicated by wrist-joint involvement The diagnosis

of its occurrence depends upon the crepitation noted in the joint, associated with an increase of tenderness and swelling about the joint, supplemented by roentgen-ray pictures It will be remembered that the original infection is upon the flexor surface. The swelling and tenderness are here. When the joint becomes involved the dorsum also partakes of this Under normal conditions a depression is noted on the back of the wrist-joint to the radial side of the extensor communis tendons at the lower end of the radius This marks the site of the radio-carpal articulation. When this fills with fluid the depression is replaced by a fluctuating swelling, and in case of doubt a needle can be inserted here and the contents of the joint aspirated for diagnostic purposes This site is particularly indicated in doubtful cases since, the original infection being upon the palmar side, there is no great danger of infecting the joint if it is not already involved

TREATMENT IN CASES WHERE THE WRIST-JOINT IS INVOLVED

Besides the incisions suggested above for drainage of the forearm, special considerations must be borne in mind when dealing with involvement of the carpal, carpo-metacarpal, or carpo-radial articulations. Owing to the frequently associated involvement of the radial bursa, this will generally have been opened, and in serious cases the necrotic tendon will have been removed. The fact that when this occurs the patient is generally of advanced age will emphasize the necessity of radical treatment rather than temporizing measures which might be justifiable in younger individuals This holds true not alone for the resection of the tendon, but also as regards removal of the carpal bones In every one of the cases reported above, in which the joint became involved, a resection of some or all of the carpal bones was indicated Even

in younger individuals, unless prompt and radical incisions are made, associated with careful after-treatment, unfortunate sequelæ are likely to result. That it does not always ensue I am convinced by two patients who came under my observation, in which the joint made a recovery without necrosis of the bones, but here prompt drainage had been instituted However, I cannot speak with authority upon this point, since, fortunately, my own experience with this serious sequela has not been extensive In some cases it became necessary to remove necrotic bone, and in these cases a complete removal of all carpal bones was found advisable A study of the anatomy suggests the cause of the tenacity of this infection and the rapidity with which it involves the entire joint. We note that, as described by Gray,[1] while there are four separate synovial sheaths, yet in reality the joint proper has only two, and, moreover, these two are so intimately associated that the least erosive action on the part of an infection lying in one would cause an extension to the other Moreover, the removal of any of the more important carpal bones in the radio-carpal articulation will permit of immediate extension in the synovial spaces about the distal bones In those cases where the infection is

[1] Although all the authors agree in describing the radio-carpal synovial sac as isolated from the carpal, there is great variation in the description of the carpal sacs Cunningham and Quain follow Allen Thompson, and, in addition to the radio-carpal and triquetrum-pisiform, describe one sac between the lunate and triquetrum above and the os capitatum and hamatum below, another between the navicular above the multangulum majus and minus below, these being separated from the carpo-metacarpal sac below, with a single sac between the multangulum majus and thumb metacarpal Gerrish follows Testut, giving the same description with the exception that he divides the carpo-metacarpal between the middle and ring metacarpals into two Joessel, on the other hand, shows a communication between the carpal and the metacarpo-carpal on the radial side, with a separate sac for the metacarpo-carpal of the ring and little finger metacarpals Gray shows a general communication between the carpal and metacarpo-carpal synovial sacs This difference of opinion simply demonstrates that the communications vary in different individuals In a surgical consideration we should expect a more or less free communication, consequently in this discussion I have followed Gray's classification.

confined to the radio-carpal articulation we may attempt to remove the carious bone by the curette and give drainage to the joint, with the hope of preventing extension to the carpal synovial sac If, however, any bone is removed the whole carpus should be resected My own experience and the study of reported cases show that removal of some of the bones is generally followed by subsequent removal of the remainder The probable involvement of the radio-ulnar synovial sac should be borne in mind, since it seems to be a frequent complication The ultimate result following complete resection is much better than one would expect

When the carpal synovial sheath is involved, however, we may remove any of the carpal bones with the exception of the triquetrum, lunate and navicular without danger of causing a spread to the radio-carpal joint The intimate relation of the ulnar sheath, as already pointed out, results in early involvement of the os capitatum (Fig 194)

The infection of the synovial sheath between the pisiform and triquetrum may spread to the carpal articulation, as in Case XXX In relation to which Forssell quotes from Henle to the effect that anatomically there is frequently a communication between the two sheaths

There is often considerable erosion of the bones before the diagnosis is made We are urged, therefore, to watch with special care aged patients with bursal infections and to open the joint at the first evidence of definite infection I am convinced, however, that this complication should be a rare one in those cases submitted to early and radical treatment for infections of tendon sheaths and soft parts. In every case coming under my observation the sheath had not been opened until long after the infection had begun Early in the course of joint involvement free incision will give great possibility of a cure without the necessity for resection But should the indication

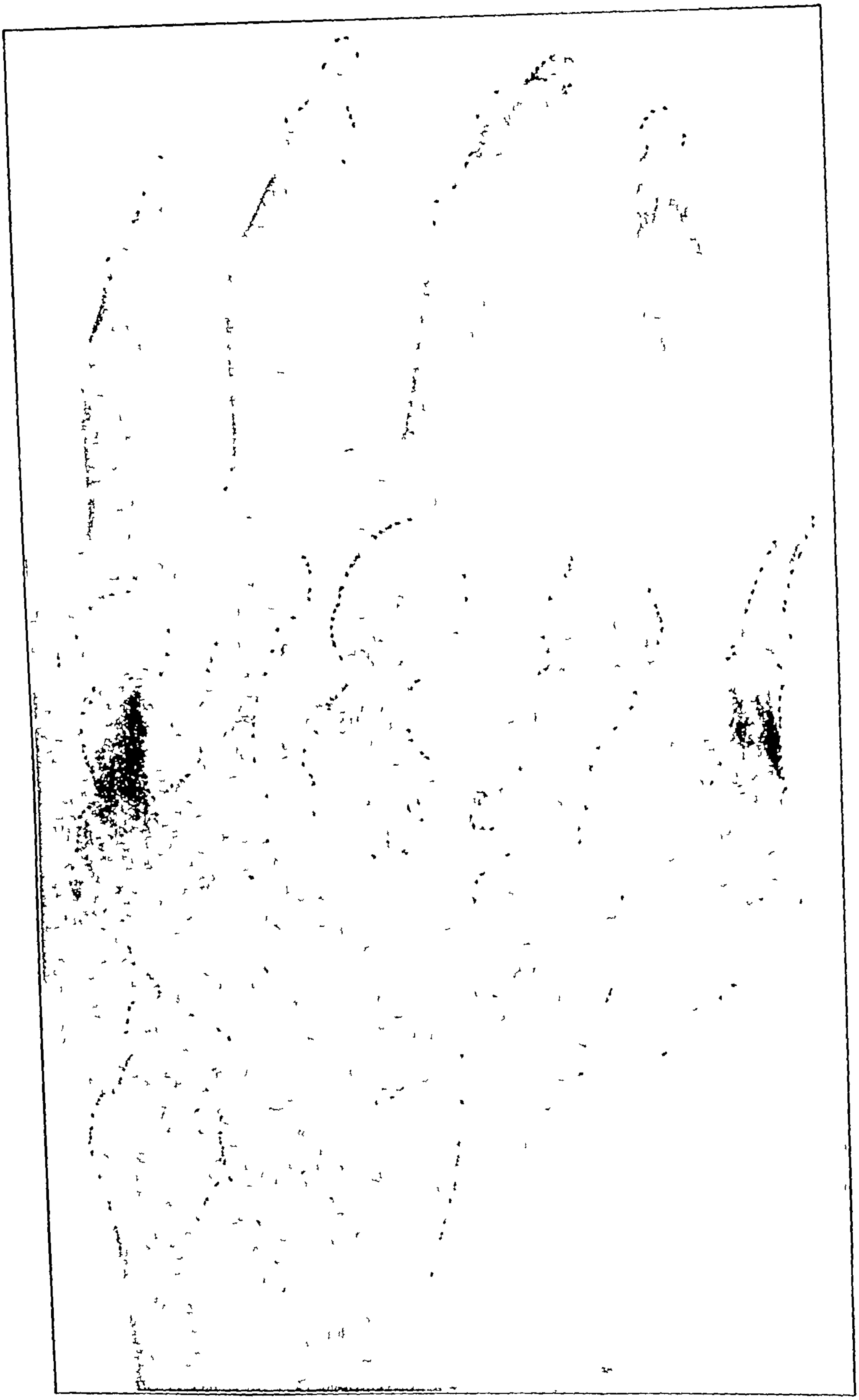


FIG 195 —Roentgen-ray photograph of hand (Case XXXII) Necrotic bone was removed from the wrist and the three metacarpals (See photograph of hand showing present function—Fig 196)

arise for curettage or removal of the carpal bones, it should be done thoroughly and completely along the lines suggested above In all cases of osteomyelitis, whether of the metacarpals or carpals, absolute immobilization is essential The following typical case illustrates the result we commonly secure in the neglected cases

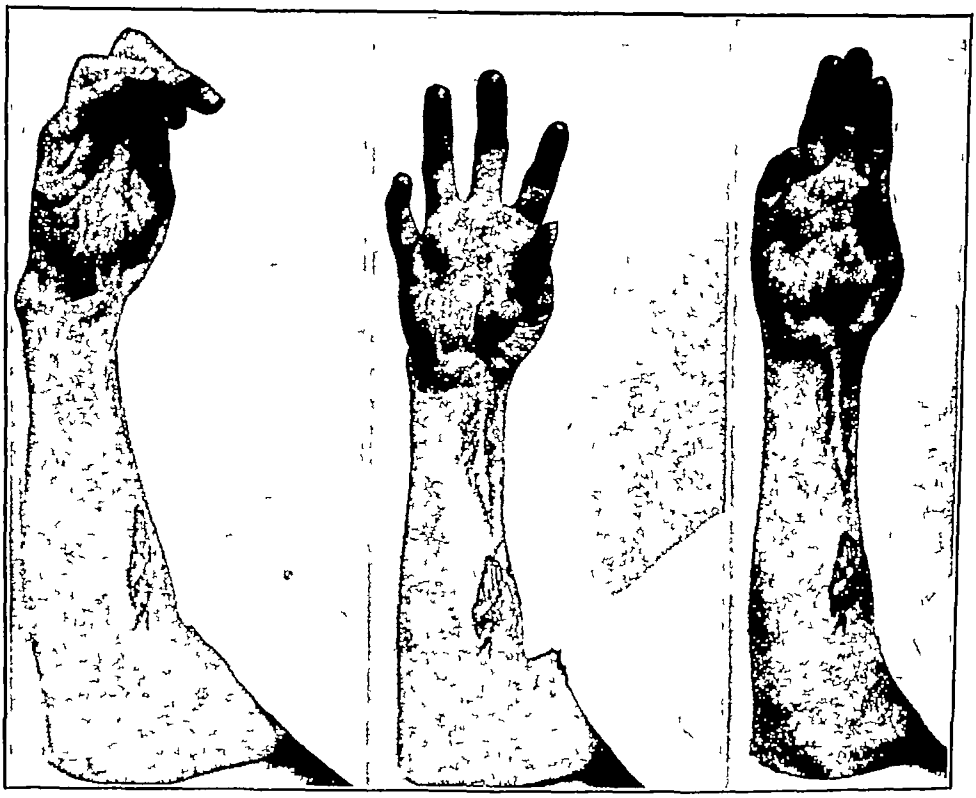


FIG 196 —Hand of patient described in Case XXXII two years after operation

CASE XXXII —S, Post-Graduate Hospital The patient suffered from a previous tendon-sheath infection of the ulnar and radial sheaths I saw him after three months of chronic infection, when there were multiple sinuses both on the dorsum and flexor surface of the wrist from the joint, with lateral and distal sinuses upon the dorsum of the hand from osteomyelitis of the metacarpals of the index, middle, and little fingers There was no involvement of the metacarpo-phalangeal articulations, in spite of the long-continued infection and extensive osteomyelitis The roentgen-ray picture clearly showed the location of the foci All of the carpal bones were removed and the necrotic part of the metacarpals The hand rapidly recovered. All discharge ceased within four weeks Almost all function was lost (Fig 195).

I have been surprised to find that now after two years he has developed considerable function of the fingers and hand, so that he can hold a glass and perform other gross functions with the hand as well as write, hold a knife and fork, and do other similar acts (Fig. 196). I have had a similar experience in two other cases.

FOREARM INVOLVEMENT WITH SECONDARY HEMORRHAGE

One of the most serious complications met with in the later stages of forearm involvement is that of hemorrhage The onset of a sudden, profuse hemorrhage in a patient who is unable to care for himself in the temporary absence of attendants may lead to an immediate lethal issue The condition is especially dreaded, since the surgeon looks upon the condition as most difficult to handle, and he fears to undertake the dissection which he believes to be necessary to find the point of hemorrhage and ligate He therefore temporizes with a bandaging of the arm and tamponade, only to be subjected to greater anxiety on account of a subsequent hemorrhage It would seem that this complication may be successfully dealt with if the surgeon will only have in mind the following facts:

1 The vessel nearly always at fault is the ulnar

2. The surgeon should not temporize, but cut down upon and ligate at once the bleeding vessel

The reason for the involvement of the ulnar vessel is seen by examining the cross-sections (Figs 38 to 42, and 143), in which it is shown that the pus early involves this vessel The line of extension is along this vessel, both up toward the elbow and downward to the ulnar side of the forearm. The radial is well separated from the space in a majority of cases

My statements do not depend alone upon my anatomical and experimental studies Clinical proof in support of it can be adduced from my experience, and also from

numerous cases reported in the literature I will let two cases suffice for that: one that came under my observation, and one from the service of Professor Velpeau This latter is added for the further reason that the examination of the amputated arm serves to give further corroboration to my statements as to the position of pus in these cases, a fact which cannot be definitely proved except by such examination or postmortem My own case I shall report briefly

CASE XXXIII —Mr H Referred to Dr Richter at the Post-Graduate Hospital, with whom I saw the patient in consultation

Ten days previous to the onset of the first hemorrhage the patient had suffered from a tendon-sheath infection of the ulnar and radial bursæ, with extension into the forearm The infection had not been opened promptly, and even after the primary incisions the drainage from the forearm had not been satisfactory Dr Richter had made free drainage, but by that time the vitality of the vessel had been impaired A few days later sudden profuse hemorrhage occurred, which jeopardized the patient's life before it was discovered by the nurse A constrictor about the arm and tamponade completely controlled the hemorrhage, and it was felt that it would not recur However, two days later a second profuse hemorrhage occurred, and the ulnar vessel was cut down upon as soon as the patient had recovered from the severe shock The source was found to be the ulnar, as had been prognosticated It was ligated with catgut, and the patient made an uneventful recovery Function in the hand, however, was impaired

The history of the following case, made the more interesting by the personal attention of the eminent Professor Velpeau, serves further to emphasize the possibility of hemorrhage from ulceration of the ulnar vessel. The presence of the fistulous tracts near the transverse carpal ligament suggested the necrosis of the carpal bones which was present, and the deep position of the pus in the forearm is worthy of note The whole clinical picture was one of extensive involvement of the wrist-joint, deep phlegmon of the arm, and the infection of synovial sheaths which at a later day would in all probability have been relieved by operative procedure.

CASE XXXIV (Bauchet) —Whitlow of the left thumb caused by a prick of a needle, multiple abscesses produced by the spread along the synovial sheath to the wrist and forearm Hospital gangrene complicating the abscesses of the wrist and following the tissues along the ulnar artery, severe hemorrhage, tamponade, tourniquet, gangrene of hand and forearm, amputation, danger of hospital gangrene in stump Recovery

Patient, aged fifty years, in the service of M Velpeau, Charity Hospital, sick for two and a half months, entered April 25, 1851, was dismissed August 13

About two and a half months ago the patient pricked the thumb of his left hand with a needle There resulted a phlegmon of this digit which extended rapidly over the whole hand, abscesses formed on the palmar aspect of the finger and hand, some of which opened simultaneously and some of which were opened by a bistoury, the swelling persisted, and even spread through the entire thickness of the wrist and forearm, along the synovial sheath

On the palmar face of the wrist one notes several sinus openings from which passes a purulent fluid, viscid, clear, and thready, by pressing the palmar surface from below upward, one causes this liquid to flow back These openings seem to communicate freely with the synovial sheaths of the flexor tendons of the fingers at the level of the wrist

The inflammation spreading from the hand to the forearm along these channels is very intense, and presents the characteristic of a diffuse phlegmon During the next seven weeks the patient was treated in an expectant manner

June 20 Appearance of hospital gangrene The openings on the palmar aspect of the wrist are larger, puffed up, mushroom-like, and forming a large projection showing a spongy, fungous, grayish aspect

June 28 Growth of the wound, which now covers the whole palmar face of the wrist. Sinking of the mushroom-like elevation of flesh All the tissues between the skin and the bones of the wrist are in a stage of putrilage, and the flexor tendons are floating in this decomposed matter These tendons are stripped of their sheath, exfoliated, and have lost their silvery appearance

June 29 During the preceding night considerable hemorrhage from the ulnar artery

After several days hospital gangrene developed in the hand, and Professor Velpeau amputated at the upper third of the forearm The patient then made a rapid recovery

Pathological anatomy of the amputated member A careful dissection permits one to ascertain that the ulceration involves only the ulnar artery, the central end of this artery is stopped by a blood-

clot The radial artery in the gangrenous portion is filled with fibrinous clots

Upon examining the other tissues, one notes at the level of the focus of the palmar abscess purulent trails which ascend the length of the forearm in the tendinous grooves, and the length of the aponeurotic sheaths of the muscles of the anterior aspect of the forearm, to the level at which the forearm was amputated One notes, moreover, an infiltration of purulent fluid between these grooves and these aponeurotic sheaths The connective tissue of the forearm is infiltrated like lard The tissues of the hand are completely sphacelated, dead, and black

Treatment in Cases of Secondary Hemorrhage.

As has already been stated in dealing with this subject, those cases showing hemorrhage should not be temporized with As soon as the patient has recovered from the primary shock and before the temporary tamponade has been removed, the surgeon should make an incision over the ulnar vessel To do this an incision should be made about the upper third of the forearm on the ulnar side, designed to reach the artery between the flexor digitorum sublimis and the flexor carpi ulnaris The flexor carpi ulnaris is then drawn to the ulnar side and the artery searched for (Fig 42) The site of the hemorrhage should be sought and the vessel doubly ligated proximally and distally Tamponade and clotting cannot be depended upon Further hemorrhages are almost sure to occur and leave the patient in such serious condition that he may not survive the combined hemorrhage and infection

RÉSUMÉ

Delayed recovery is generally due to necrotic tendons, poorly drained abscesses, suppurative arthritis or osteomyelitis.

Necrosis of the distal phalanx ordinarily ends in sloughing of the diaphysis alone Joint function should be preserved Incision should be made laterally instead of upon the volar surface (See Chapter X)

In suppurative tenosynovitis with osteomyelitis the proximal interphalangeal joint is most commonly involved The proximal phalanx escapes while the epiphysis and part of the diaphysis of the middle phalanx are destroyed Conservative operations may be done with some success

Isolated involvement of the tendon sheaths may be present Incision of the sheath should expose all involved parts Poorly drained abscesses should be opened widely. All necrotic tendons should be removed

Chronic palmar abscesses frequently point on the dorsum, passing along the lumbrical canals. Palmar abscesses may be opened along these canals

Chronic dorsal abscesses may point at a distance from the focus, owing to the dorsal aponeurotic sheet

The wrist-joint may be involved particularly in aged patients with ulnar or radial bursitis The os capitatum is often the first bone involved. Early conservative drainage may be instituted, but radical removal of all the carpal bones is generally indicated especially if treatment has been delayed

Secondary hemorrhage comes from the ulnar artery. The surgeon should not depend upon tamponade, but should ligate the bleeding vessel

CHAPTER XXVII

SEQUELÆ OF INFECTIONS OF THE HAND

EDEMA FOLLOWING INFECTIONS

PERSISTENT edema, sometimes accompanied by pain and sometimes not, is one of the most distressing sequelæ of infections and injuries of the hand.

This persistent white edema appears most often in one of three forms In the first form we see slowly developing edema in the general region of an infection often mild in nature but deep seated. Operation may disclose a few drops of pus or some infective nidus such as a small foreign body The second type is the so-called "hard edema" located on the dorsum of the hand extending distally from the wrist, involving the fingers but not commonly the thumb. The third and most distressing form follows infections and involves the whole forearm or arm and hand

In the first type reference is not made to the ordinary edema that accompanies the severe chronic infections with involvement of bones, tendons, or joints, an edema that disappears after the removal of the necrosing tissue In the type under consideration the patient complains of recrudescing edema and pain at the site of some trivial injury Simple incision with evacuation of a few drops of pus seldom ends in complete recovery If a foreign body is removed the result is excellent Recovery generally follows the excision of a considerable section of tissue followed by drainage, but even here disappointment may follow and the process continue a chronic course with gradual recovery

The second type, the hard edema of the dorsum of the hand, may follow injury usually of a minor type, but it often originates in some slight infection in the neighborhood of the wrist The process is generally not very painful but persists. All ordinary treatment is futile. No focus of infection is found upon operation The skin is dry and later becomes tough and inelastic, often with dry scales If pain is induced sweat may be seen on the other hand while the injured hand remains dry. The hand is white and warm, not blue and cold At the inception of the trouble there may be hypo- or hyperalgesia and at times severe pain for some days but this soon disappears

The genesis of the edema is not definitely known The arterial oscillations may be normal but are often intensified There is no evidence of venous engorgement or phlebitis Tinel and Moncany believe that the circulatory obstruction is to be found in vasoconstriction of the capillaries and venous system, and that the serous transudation occurs from the arterioles They support this from the observation of the suppression of sweat and its reappearance parallel to the functional improvement of the hand and the contrast of this white, warm, traumatic edema with the blue, cold edema of arteriolar angiospasm. André-Thomas and Kudelski disagree with this explanation of Tinel and Moncany, and suggest that the edema may be due to an inflammatory process with some predilection for the venous system with subsequent involvement of the lymphatics and other tissues Which assumption is correct or whether some other pathogenesis must be sought one cannot say It appears certain, however, that following the long-continued angiospasm or venous inflammation one finds after many months connective-tissue proliferation and vascular change with obliteration of the veins.

While the typical picture is that of edema confined to

the dorsum of the hand and fingers, exceptionally the palm and thumb or the whole arm may be involved.

Spontaneous recovery is the exception and the results of treatment are most unsatisfactory Hot baths, massage, splinting, and local applications very seldom improve the condition Apparently cold, due to its vasoconstrictor action, aggravates the condition Dry, warm applications seem to relieve the patient more that moist heat. Active movements are of more benefit than rest. Voluntary contraction is superior to massage and passive movements. In Walther's case all these various local treatments failed, the persistent pain, however, was controlled by the application of collargol. Gradual, systemic compression has been tried without result The same is true of the use of diathermy Barré believes that there may develop, within the tissues, small neuromas which may be removed by surgical operations Rebulla recommends in the early stages a deep longitudinal incision The excision of fascia and subcutaneous tissue has helped in some cases and others have reported benefit from the insertion of silk drainage threads.

Leriche, Tinel and others believing that the lesion originates in a sympathetic spasm have advocated early sympathectomy In addition to these surgeons, Brandao, Wertheimer, and others have reported satisfactory results from sympathectomy in one form or another The results have not been constant, however, some cases responding to periarterial sympathectomy alone, others to removal of the stellate and second cervical sympathetic, while in some removal of the entire sympathetic chain has been necessary After any one of these operations there has almost always been a temporary cure, not infrequently, however, the edema has reappeared after two or three months A sufficient number of patients has not been subjected to this treatment nor have those so treated been observed for a sufficient period postoperatively to

make certain of the permanent benefit of the procedures. Even though sympathectomy may prove to be indicated it would appear that, if it is delayed for some months after the beginning of the edema, local operative procedures must be carried out after the nature of the Kondoleon operation to favor the formation of new lymphatic channels The subcutaneous connective tissue should be excised and windows made in the fascia

The third type, massive edema of the whole arm or the forearm and hand with excruciating pain, is still less understood In the cases I have seen there has been a history of infection of the acute type, often with lymphangitis In no case that I have seen has there been any marked suppuration No type of local treatment has been of avail Brandao reports a somewhat similar case except that there was no history of trauma or infection. He performed periarterial sympathectomy and removal of stellate and second dorsal sympathetic at successive stages with temporary relief in each instance Some months later the whole sympathetic chain was removed with recovery for at least three months when the patient was last seen.

It is probable that the "hard edema" just discussed and this type are closely allied, and both must await further clinical and experimental studies before their nature will be understood and their proper treatment established

ANKYLOSIS, CONTRACTURES, AND LOSS OF TISSUE

If treated early and properly most infections of the hand should be controlled with little or no resulting disability This holds true especially for the fascial-space infections and lymphangitis Some disability may follow tendon-sheath infection even if treated promptly, generally, however, this is slight even in the ulnar and radial bursal infections, consisting only of disability of the little

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obliterated and the majority of the tendons are indistinguishable as tendons from the surrounding connective tissue A few of the superficial flexor tendons may be dissected out from this scar tissue and recognized The flexors of the little finger are frequently completely lost and the same holds true of the flexor of the thumb. The median nerve may be completely destroyed for some distance The transverse carpal ligament is involved in

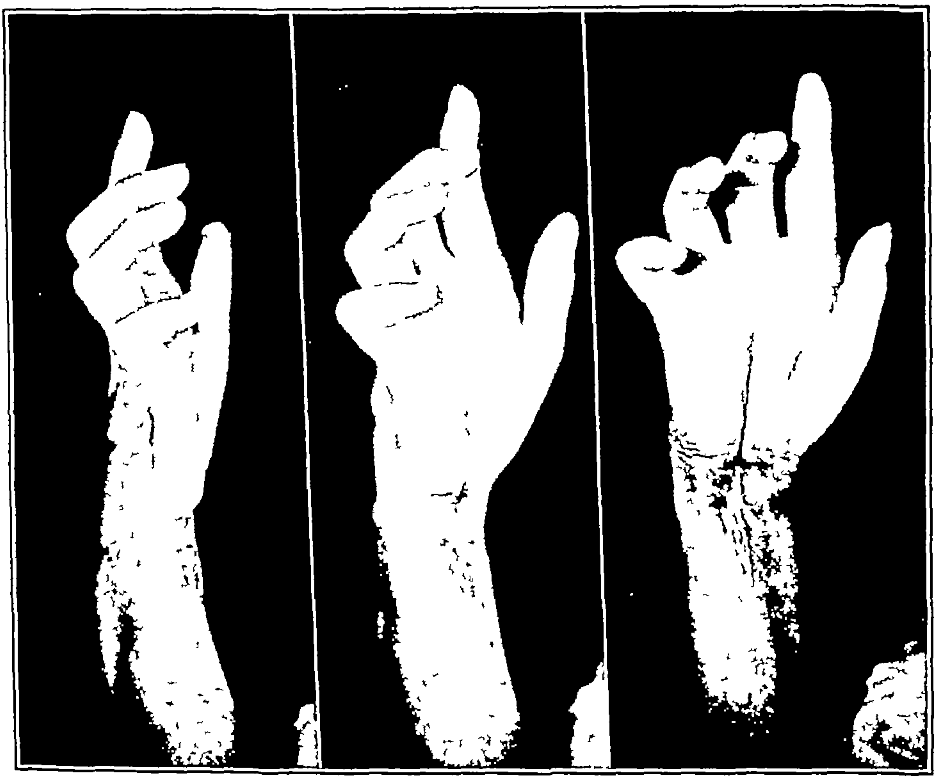


FIG 197 —Result of neglected ulnar and radial bursal infection

the connective-tissue formation In the palm, the tendons of the index, middle, and ring fingers may frequently be isolated and less often those of the little finger and thumb On the dorsum, particularly if ill-advised incisions have been made here, the tendons are a part of the connective-tissue mass although more easily dissected out than those upon the flexor surface In the forearm, connective-tissue contraction has taken place about the median and ulnar nerves and the ulnar artery, compressing

finger. Felons may end in unsightly scars, impaired nail growth, or distortion of the distal phalanx incident to loss of the diaphysis. Injuries by teeth at the knuckle-joint may produce ankylosis of the joint through infection The loss of skin from carbuncles may entail skin grafting.

In the severe infections of the tendon sheaths with delayed treatment serious sequelæ are often seen If the infection has involved a finger alone, we not infrequently have a loss of the tendons The phalanges are extended, with fibrous or bony ankylosis of the proximal interphalangeal joint The finger, however, can be flexed at the metacarpo-phalangeal joint The tissues are atrophic and sensation is impaired

It is in the neglected infection of the ulnar and radial bursæ that we find the most disastrous consequences The anatomical and clinical evidence already adduced shows the tendency for the infection to spread along the bloodvessels and nerves This leads to compression of the bloodvessels, lymphatics and nerves by scar tissue with ensuing trophic changes Ankylosis of joints and contraction of muscles with adhesions about the tendons or their destruction adds to the disability

One who has not dissected these hands can hardly realize the extent of the destruction of tissue and the distortion of the anatomical structures found as a result of the infection In those cases in which the tendon sheaths are involved—and these are by all odds the most serious type one finds—the synovial sheath is entirely obliterated, the endothelial lining is entirely lost, there is a complete fibrous union between the tendon and its sheath throughout its extent, and incident to the flexed position of the hand and the changes characteristic of all connective tissue, the tendons have been shortened At the wrist under the transverse carpal ligament, the ulnar and radial bursæ and the intermediate sheaths are completely

one of destruction of nerve and blood supply with massive connective-tissue contraction about structures that have a most delicate function

As to the clinical appearance, one sees a glossy skin with atrophied hypothenar, thenar, and forearm muscles and shrunken intermetacarpal spaces, the thumb frequently adducted and fixed to the side of the hand, the fingers flexed upon themselves and extended on the hand, with fibrous ankylosis of the finger-joints, and frequently osseous ankylosis at the wrist-joint producing an immobile, shrunken claw-hand, absolutely functionless and useless Moreover, owing to the poor nerve and blood supply, the hand is often the seat of ulcers, frost-bites, and inadvertent burns We have here drawn the picture of the worst type seen in these cases, that produced particularly by neglected ulnar and radial bursal infections in which the pus has been allowed to rupture into the forearm and frequently into the palm of the hand and the wrist-joint Those cases in which the bursæ are opened promptly end frequently with contracture of the little finger but a fairly satisfactory result as far as function in the hand as a whole is concerned

If an individual finger has been involved and the tendon lost, the phalanges are generally extended, the finger straight and ankylosed in this position—movement is possible at the metacarpo-phalangeal joint but, being straight, the finger is much in the way

Patients presenting themselves have generally had their infections some months or years before and have tried all manner of massage without benefit Indeed, in view of the pathological picture presented in these cases, it would be most remarkable if by such procedures one could produce any result

For a number of years a study has been carried on in these cases with the hope that some procedure might be developed that would offer relief to these sufferers.

them and binding the muscles together Moreover, the tendons above the wrist-joint and the deep flexor muscles are united by firm connective-tissue bands to the pronator quadratus and the interosseous septum

Joint changes have also occurred These are noticeable in the interphalangeal, metacarpo-phalangeal, and wrist-joints. Owing to the inflammation about the phalangeal joints, they are rather firmly fixed in flexion while the metacarpo-phalangeal joints are generally fixed in over-extension with peri-articular contraction and intra-articular adhesions, frequently not insurmountable, but difficult to deal with The thumb is generally bound to the side of the hand in a functionless position At the wrist-joint, in the severest cases, considerable destruction of the carpal bones may have occurred, ending in ankylosis of the joint, often in a bizarre position

The muscles have also undergone change Those in the forearm have lost their tone, fibrosis has taken place and, hence, although active are impaired The most unfortunate sequela, however, is that produced in the lumbrical and interosseus muscles These are frequently entirely destroyed, due either to inflammation, destruction of innervation, or a lack of blood supply The nerves have also partaken of the general devastation owing to the direct spread of the infection from the hand into the fore-arm along both the median and ulnar nerves The nerves are surrounded by connective tissue and their vitality and function impaired In the carpal canal it is frequently impossible without the greatest of care to distinguish the nerves from the surrounding scar tissue of the tendons If there has been pus in the middle palmar and thenar spaces, the digital branches of the nerves have also been pressed upon The bloodvessels have suffered in the general connective-tissue contraction The skin is glossy and shows the effect of a lack of both nerve and blood supply The pathological picture, therefore, is

CHAPTER XXVIII

PHYSIOTHERAPY AFTER INFECTIONS OF THE HAND.

THE after-treatment of patients suffering from injuries and infections of the hand is frequently so neglected, or carried out in such a haphazard manner, that the ultimate results fall far short of what might be attained

The primary requisites in the treatment of hand infections are an adequate knowledge of the anatomy of the hand, of the underlying pathological process present, and of the proper methods of surgical treatment Of equal importance in securing a perfect result is a comprehensive knowledge of the various methods of treatment which will bring about a restoration of function after the infection has been controlled

In general the pathological process present in a severe hand infection may be divided into three stages first, the stage of spreading infection; second, the stage of repair, and third, the stage of fibrous-tissue formation During the first stage adequate drainage, maintenance of asepsis in the dressing, and rest in the "position of function" are the essential factors, during the second period gentle passive motion is begun, and limited active exercises are added as soon as the infection is under control, by the time the third stage is reached, gentle but frequently repeated exercises, both active and passive, should be well under way

It is difficult to lay down hard and fast rules, for in every case the treatment depends upon the location, the extent, and character of the infection The first step, obviously, is to overcome the infection. As a rule, and this is of particular importance in infections involving tendon

Owing to the fact that it takes a comparatively long time to obtain results and that nor only must one correct the condition, but the muscle tissue, nerves, and other structures must regenerate, it is impossible to state categorically what can be promised in these cases Much, however, can be done both by prophylactic measures and active treatment to preserve and restore function The surgeon should constantly have in mind that he is not only attempting to overcome the infection but also to preserve function In those patients in whom function has been lost, much can be done by physiotherapy, proper splinting, and operative procedures to restore to the patient a useful though crippled hand

substituted for the hot pack, both passive and active movements are carried out more extensively, in cases in which the infected area has been drained early, gentle passive motion may be carried out for fifteen-minute periods three times daily after the fourth or fifth day, preferably while the hand is immersed in the bath The importance of this procedure in preventing permanent stiffness in those cases in which the tendon sheaths are involved cannot be overestimated

The best guides to the amount of exercise that may be borne with safety are the presence or absence of pain and the patient's general reaction, as evidenced by the temperature and pulse The proper degree of exercise should not be painful The patient may be apprehensive at first, but if the fingers are moved gently there should be no actual pain

If the temperature rises sharply within an hour after exercise, one must limit it to a shorter time and a smaller range of movement Occasionally the reaction to a virulent infection is so great that a very limited amount of exercise will bring about a sharp temperature reaction In such cases one must be satisfied with preventing adhesions, until such a time as the patient has developed a greater immunity to the infection

By the time healing has taken place, *i e*, by the end of the second week in the average case, exercises supplemented by other agencies for promoting nutrition and repair of the tissues should be well under way

These agencies may be grouped under several heads

1 Hydrotherapy and radiation
2 Massage
3 Electrotherapy
4 Exercise
5 Occupational therapy
6 Psychotherapy.
7. The use of splints. (See Chapter XXIX)

sheaths, all drainage is removed at the end of forty-eight hours As soon as possible, usually within four or five days, the massive hot dressings, which encase the forearm and most of the arm, are replaced by an arm bath, long enough to accommodate the hand and forearm, and deep enough so that the elbow and larger part of the arm are immersed.

This may be used continuously or during three or four twenty- to thirty-minute periods during the twenty-four hours In the latter case the hand and forearm may be exposed to the light of an arc lamp, or of a cluster of incandescent bulbs for an hour or longer after each immersion The arm bath permits the passive motion which is impossible with a big hot pack, and makes active movements visible to the patient and therefore easier of accomplishment

The use of the hot pack, hot bath and electric light at this stage is carried out with the idea of assisting in every way the natural forces of the body tissues in combating the infection We shall have occasion to speak of them again from another standpoint

During the active treatment the hand, fingers and thumb should be maintained in the "position of function" (see Chapter XXIX)

Usually within seventy-two hours after operation gentle passive motion is begun, and carried out for a few moments at the daily change of dressings These movements should be given slowly and gently, after the manner of "relaxed" movement described by Mennell, up to the point of pain, and the return to position should be with equal care and gentleness Care should be taken that all movements of the fingers and thumb as well as of the wrist and pronation and supination of the forearm are performed The patient is also encouraged to move the fingers gently by his own muscular contractions, if such movements are not painful As soon as the arm bath is

The douche or spray may be used in a similar way

The use of the arc light and of clusters of incandescent bulbs has been mentioned as a part of the treatment in controlling infection Like moist heat the heat of an electric light serves to produce an active hyperemia that is the most important factor in improving nutrition. The beneficial effect of light as well in destroying organisms and stimulating the nutrition of the superficial tissues needs no comment

MASSAGE —Massage is most effective if preceded by a preliminary preparation of the part by hydrotherapy or radiant heat, for the same reason that a coach "warms his men up" before sending them into an athletic contest Its early use along with passive motion is important in the production of a functioning hand, particularly in those cases where infection has spread upward along the forearm and involved the muscle bellies themselves

In the early treatment attention must also be given to the upper arm The massage must be purposeful Stroking and gentle kneading movements with a moderate amount of pressure should be used for the nutritional effect The pressure should be in the centripetal direction for the purpose of assisting the venous circulation

Deep heavy pressure is not required except when adhesions and contractures have formed When this has occurred a circular motion with deep pressure moving the outer tissues over the underlying ones for the purpose of stretching will do much toward loosening and stretching of scars and adhesions Care should be used to avoid friction over recently healed, tender scars

ELECTROTHERAPY —The galvanic current is of value in promoting nutrition because it stimulates muscle contraction and increases the vascular flow at the point of application

The muscular contraction caused by a galvanic current occurs only at the making or breaking of the current.

Some of them require the use of a considerable amount of apparatus, some depend solely on individual effort and initiative They all have one object in view—restoration of function through repair of diseased tissues, through increased nutrition, and through re-education of muscle groups. We should never permit ourselves to lose sight of this object in the contemplation of new or fanciful names or of elaborate apparatus, nor attempt to make one method of treatment serve in every case Rather we should try to discover what factors—whether muscle weakness, adhesions, joint involvement, nerve involvement, or scar-tissue formation with diminished blood supply—are chiefly at fault, and choose the line of treatment in accordance with these conditions

HYDROTHERAPY AND RADIATION —The value of hydrotherapy depends chiefly upon its effect on the bloodvessels By immersing the arm in a hot bath, the capillaries and arterioles are dilated, the part becomes hyperemic, the tissues are softened and relaxed to such an extent that a hand that was cold, stiff and painful may become capable of a considerable degree of motion

If the inlet jet of the bath is set at an angle or if air under pressure is forced through the bath the beneficial effect is much enhanced by the "massage action" of the swirling, bubbling water Such devices, known as the "whirlpool baths" or the "eau courante" of the French, were largely and satisfactorily used throughout the World War.

Plunging the hand and forearm alternately into baths at a temperature of 110° and of 60° F., the so-called contrast baths, are of value by reason of the alternate vasodilatation and vasoconstriction of the bloodvessels produced by the varying temperatures Such a procedure improves the vascular tone by stimulating the smooth muscle of the bloodvessels themselves, and is of especial value in cases with considerable scar-tissue formation

help to stretch contractures and increase the range of motion in stiffened joints. Such exercises should be carried out slowly and gently, never with quick, jerky movements They should be preceded by the application of heat.

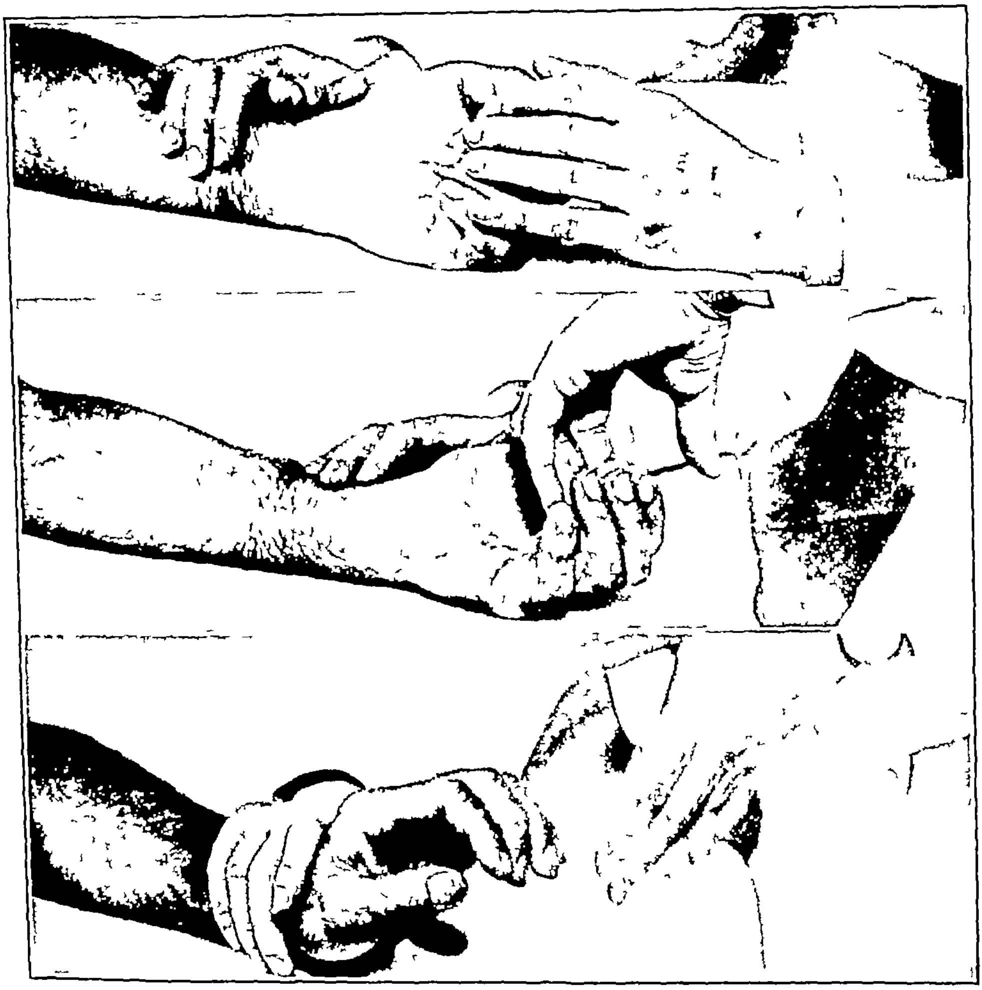


FIG 198 —Massage must be purposeful, with exercises designed to develop active movements

Passive movements for the purpose of stretching contractures should not be confused with the passive or "relaxed" movement described above for early treatment

Massage may be given over the joint while it is being stretched and over the contracted muscles while under tension Short periods of massage may be interspersed

This may be accomplished by means of an electrode with an interrupter handle

A gradual wave-like contraction may be obtained by galvanism in the form of the sinusoidal current as produced by certain especially designed apparatus The induced or faradic current may be used to produce muscle contraction by stimulation of the nerves supplying the muscles in question This approaches more nearly the normal physiological stimulation of the muscle

Electrical muscle stimulation is of value as an adjunct in restoring the function of wasted and atrophied muscles, but should not be used as a substitute for active exercise

The treatment of joint and muscle injuries by electrical stimulation may be begun as soon as the infection is under control

Special coils have been devised by which the strength of the current may be graduated by slowly pushing in or drawing out a soft iron core which is a part of the induction coil itself Bristow believes that the secret of restoration of muscle function lies in the graduation of the contraction, that one should begin stimulation with the minimum strength of current, gradually increasing it until the maximum strength that can be borne without pain is reached, and then as gradually decreasing it He emphasizes the fact that stimulation should never be painful, and that one must stop before the muscle becomes fatigued He suggests in an average case stimulating the various muscle groups four or five times for a minute or two in turn and gradually increasing the number and duration of treatments as the condition improves There is no doubt that this method possesses very definite advantages, particularly because it is possible to control definitely the strength of the stimulus

Exercise —Movement of injured tendons and muscles may be passive or active Passive exercises may very well be carried out in conjunction with massage They

function if the patient has sufficient intelligence, energy and will-power Unfortunately most of us require other stimuli

Many different and ingenious devices have been suggested for supplying the necessary stimulus. Fig. 199 illustrates devices for exercising and stretching the flexor tendons of the fingers, for promoting abduction and adduction of the fingers, for stretching scar-tissue between

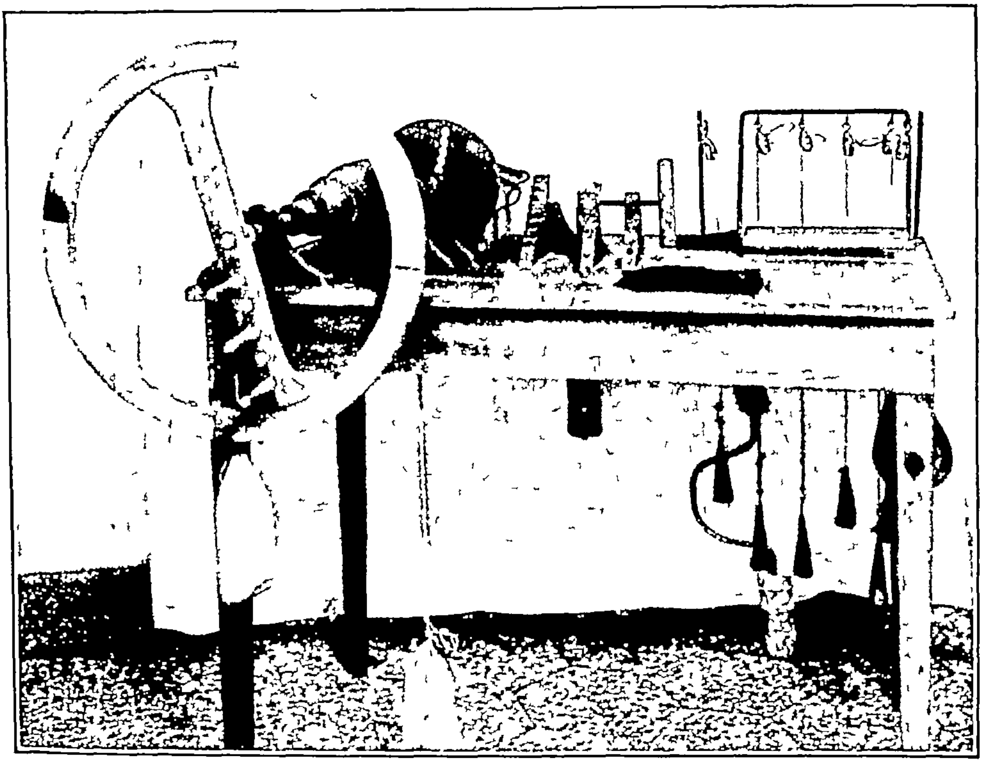


Fig 199 —Table with various devices for exercising and developing various muscles

the fingers, and for developing various other functions of the hand and wrist

Fig 200 illustrates a device for exercising the flexors and extensors of the hand The wrist and forearm are strapped down, the fingers inserted into the glove tips, and weights added until the patient can just lift them As function improves heavier weights may be substituted A special attachment serves for exercising the thumb

with the stretching movements for the purpose of relaxation, relief of pain and influence on the circulation

Twenty-four hours after the breaking down of joint adhesions passive motion should be carried out by moving the limb at least once through as complete range of motion as pain will permit These movements should be repeated each day and the part kept at rest in the "position of function" between treatments After stretching painful scars or contracted muscles and tendons massage may be carried out in about twelve hours, and followed by exercises, both passive and active

In treating the later results of injury or infection, where the main object is to re-educate or restore wasted and atrophied muscles, active exercises constitute the ideal method

Active exercise is to be understood as that which is performed by the volition of the patient Active exercises may be made progressive In very weak or atrophied muscles, assistive movements may be given, in which the patient performs as much of the motion as is possible and is assisted in the completion of the movement As strength increases the assistance should be lessened and free movements encouraged Gradually resistance may be offered to require greater effort and development of muscle strength

These may be introduced in a number of ways as voluntary exercises for the interested, intelligent patient, with the assistance of apparatus especially adapted to develop particular groups of muscles, as games of various sorts, and through the adaptation of tools which will permit the patient to work at some particular trade at the same time that he is re-educating the weakened muscles

In practically any case of joint or muscle injury passive motion of the injured part with the help of the sound member, combined with voluntary exercises carried out at the earliest moment, will do much toward restoring

forth, and thus to favor flexion and extension of the fingers. The roller is graduated in size so as to provide for different degrees of flexion function This passive exercise is supplemented by active movements as soon as the patient can grasp the roller In such cases it is usually necessary to attach finger cuffs to the cylinders to help hold the



FIG 201 Home-made mechanical devices for exercising the fingers and wrist

hand and fingers in close apposition to the roller while it is in motion.

The apparatus modified from Flint and others with its pendulum attachment (Figs 199 and 201) serves a similar purpose The fingers are slipped into the glove on the trap door in the table top, and by flexing the fingers the pendulum is moved back and forth, so as to cause flexion

Fig 201 illustrates the roller for exercising the flexors and extensors of the hand and wrist By winding up the cord supporting the weight, first in one direction and then

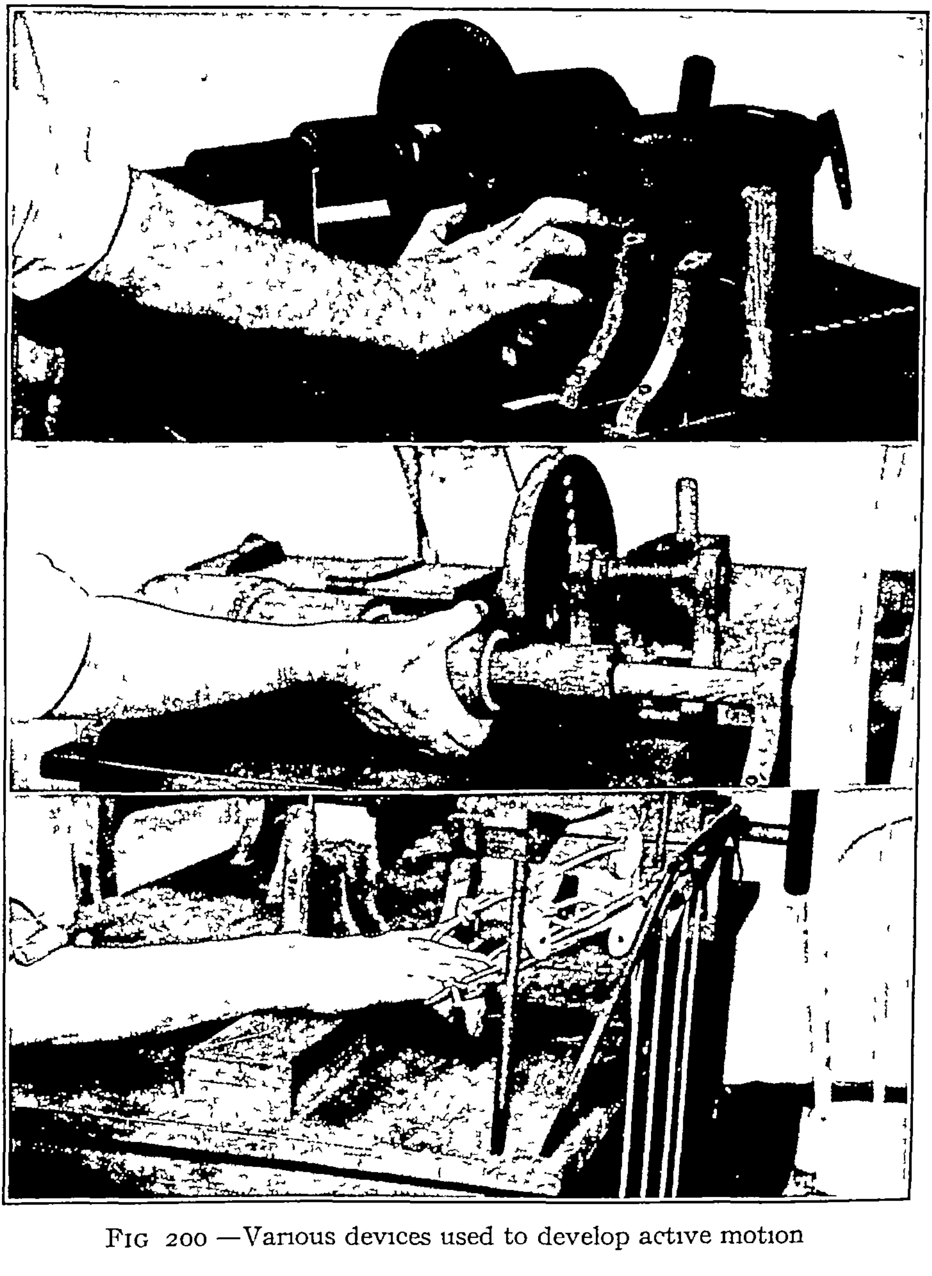


FIG 200 —Various devices used to develop active motion

in the other, the flexors and extensors may be exercised in turn In exceptionally bad cases the rope and weight are replaced by a pendulum which is set swinging in an arc of 60 degrees, this causes the roller to move back and

In all these exercises the principle of competition and of comparison is of tremendous importance Every form of apparatus should be constructed so that it is possible to determine definitely the amount of improvement from day to day—in the increased weight moved or raised, in the increased angle of flexion or extension at any particular joint, or in increased motor power

For this purpose a protractor for measuring the range of motion at any particular joint is of great value Fig. 202 illustrates such devices for measuring the degree of flexion or extension of the fingers and wrist Similar devices may be used for measuring the range of motion at the elbow and shoulder The grip may be measured by squeezing the partially inflated cuff of a blood-pressure apparatus

Games are of particular value in bringing about unconscious and effortless exercise of injured muscles. Where a considerable number of patients with somewhat similar disabilities are grouped together, competitive games offer the happiest and simplest solution of the problem of finding the necessary stimulus Very simple games will often serve the purpose The sick man not infrequently is absolutely happy with amusements that would bore him tremendously under different circumstances

For exercising the muscles controlling finger movements, playing marbles or crokinole are valuable for developing extension and piano-playing, or practising on a typewriter, squeezing a rubber sponge, manipulating molding clay, or using the so-called "runners grip" are of particular value in special cases For exercising the joints of the hand and wrist, hand ball, Indian clubs, dumbbells, bowling, quoits, and billiards are particularly helpful A glove with straps attached to the dorsum of the wrist, running over the finger tips, and buckled to the palmar surface of the wrist is a useful and valuable aid in permitting patients with stiff fingers to take part in various

and extension at the joints of the hand and at the wrist. A device for assisting in rotating the fingers may be attached A solid wheel with holes the size of the fingers, at various distances from its axis, is fitted with an axle

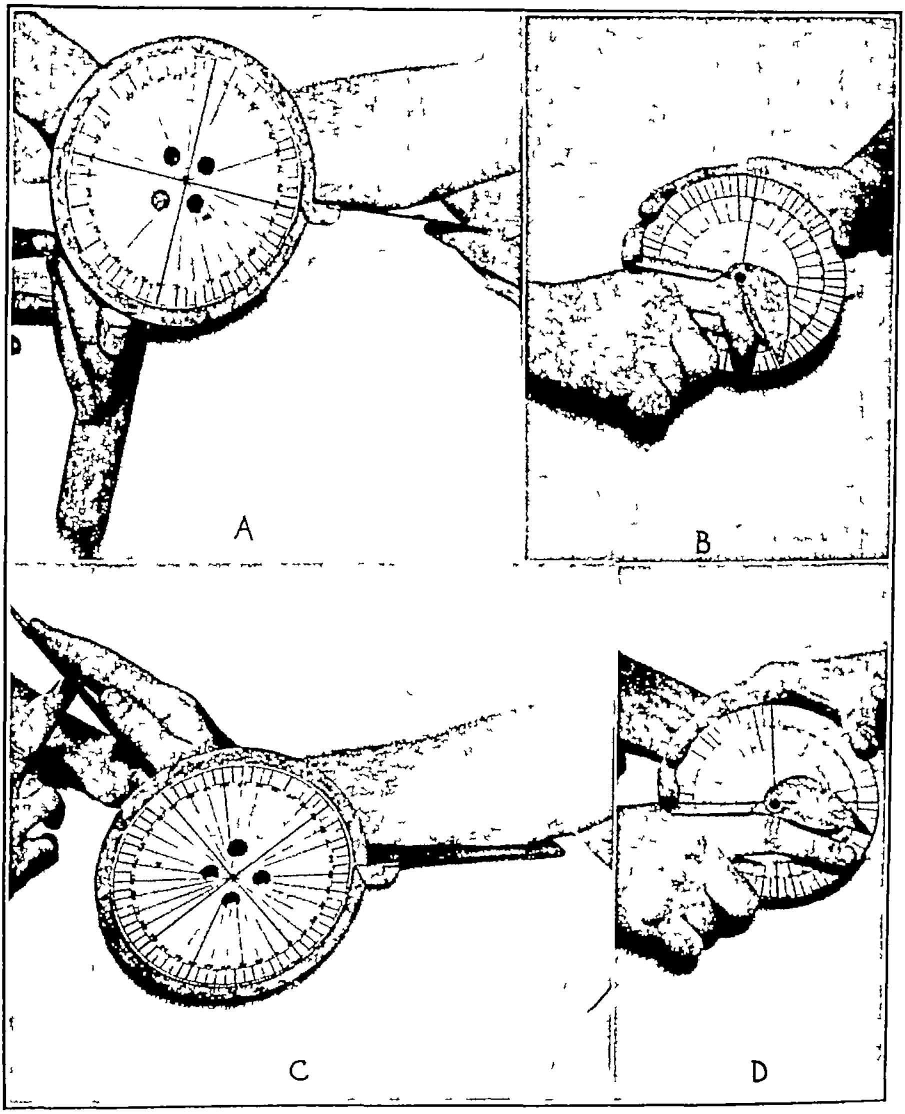


FIG 202 —Protractor (modified from Elder and others) to measure degrees of active motion

supporting a weight at the end of a cord The hand is fixed, the finger inserted first in the hole nearest the center, and the weight is wound up (Fig 199) As rotation is improved the more distant holes are used.

be enlarged to permit of its being grasped more readily With the aid of the buckled glove patients may box or punch a bag to their heart's content Other games and forms of exercise for training special muscle groups or for general development will readily suggest themselves Much depends on the enthusiasm and initiative of the one directing the treatment

OCCUPATIONAL THERAPY.—Another interesting and important method in re-educating maimed and disabled individuals is in training the injured member in the use of the implements and tools of various trades and crafts. So-called "occupational therapy" was used with ever-increasing success through the later years of the World War, particularly under the stimulating influence of Sir Robert Jones throughout the orthopedic hospitals of England, and later in our own army hospitals in the United States. The recognition of the fact that the mind of a sick man needed treatment as well as his body, and that the most successful mental treatment lay in helping him to achieve something definite—the making of a table, the setting-up of type, the repair of a motor—brought about a radical change in the methods of treating wounded men during the long stages of convalescence

The same factors—the stimulating mental effect of useful work, the hopefulness for the future that comes to an injured man in the realization that he is fitting himself for a new occupation perhaps more desirable than the one he is forced to relinquish, the diversion of interest from himself and his troubles into other channels—are just as important in the after-treatment of the injured patient in civil life as in military life.

In re-educating the wounded at the various reconstruction hospitals throughout the United States practically every mechanical trade was utilized Typewriting, type-setting, carpenter work, cabinet making, blacksmithing, modeling and weaving were only a few of the trades that

games The fingers may be flexed as far as possible about a baseball bat, a golf club, or a tennis racquet and the straps buckled If necessary, the handle of the club may



FIG 203 —Devices for keeping the patient interested in using the hand

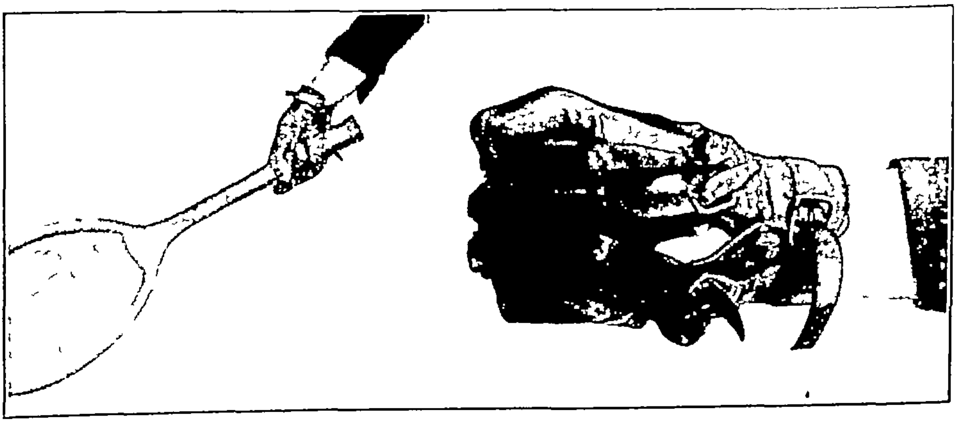


FIG 204 —Glove with straps attached to flex stiffened fingers

material becomes less and less until finally there is little or none left on the handles of the tools."

PSYCHOTHERAPY —In every case the result attained will depend ultimately upon the energy, enthusiasm and judgment that the surgeon brings to his task

The most surly or obstinate patient will respond eventually to optimism and encouragement if he realizes the possibilities of patience and perseverance Enthusiasm is infectious, and with these cases the surgeon must usually furnish the greater share This will not be difficult if he has the faith that comes with past performance.

proved of especial value for individuals with injured hands and forearms

Major H R. Allen suggested the use of modeling material, such as is used by artists and dentists, for adapting particular tools to the use of injured men. "This material becomes thoroughly soft and plastic without melting when placed in hot water for a few minutes, then if it is plunged into ice water it hardens like glass This process may be repeated as often as

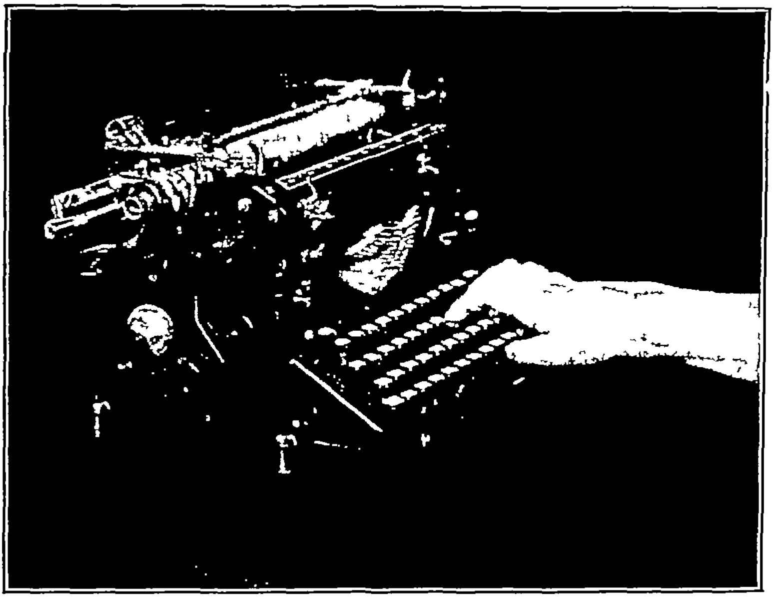


FIG 205 —The use of the typewriter often holds the interest and is a valuable exercise

desired with the same material. The material is applied to the handle of the hammer, saw, chisel, axe, or tool desired and while soft the maimed hand of the patient grasps it, closing to its maximum in the plastic material Then the tool is released and the handle plunged into ice cold water, which sets the mold The patient finds that in this manner he can use the tool with the injured hand. As function improves the mold is reset by plunging the handle into hot water, remolding and resetting. As the end-result approaches, the amount of modeling

Later the surgeon should substitute for this method the more satisfactory aluminum palmar or dorsal cock-up splint described below If more thought were given during

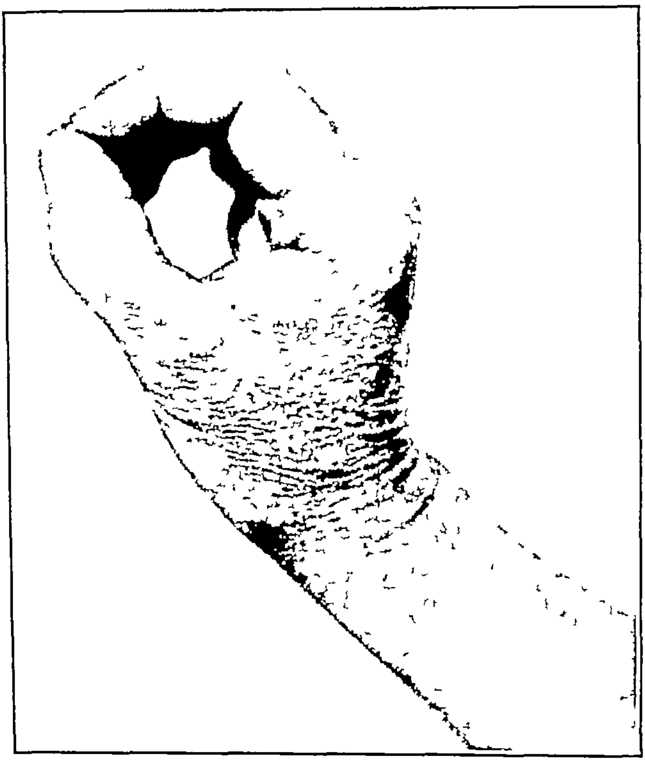


FIG 206 —"Position of function"

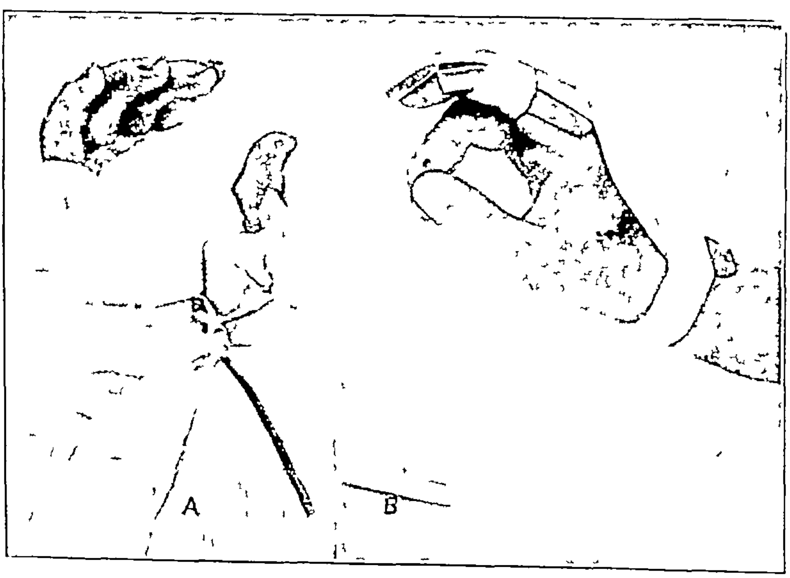


FIG 207 —*A*, Thumb drawn over into "position of function," *B*, "position of function" to be maintained if a tendon of a finger is lost

CHAPTER XXIX

THE USE OF SPLINTS AFTER INFECTIONS OF THE HAND

PROPHYLACTIC TREATMENT—POSITION OF FUNCTION

TO my mind one of the most important factors in the care of infected hands is the maintenance of the hand in the "position of function" throughout the treatment The hand should never be simply surrounded by hot dressings and permitted to lie in an extended position It should be maintained in dorsal flexion at the wrist at an angle of 45 degrees, the phalanges at the metacarpo-phalangeal and phalangeal joints should be flexed to the same angle and, most important, the thumb should be abducted from palm, adducted toward the ulnar side of the hand and rotated so that the flexor surface of the thumb is opposite the flexor surface of the index finger (Fig 206) This subject is discussed in more detail in the chapter dealing with "Function of the Hand in Relation to Infections" This position should be maintained throughout the treatment except when the hand is undergoing physiotherapy It may be secured by various means adapted to the sites of the incisions and the stage of the treatment Immediately after operation upon a palmar infection a roll of sterile gauze or bandage roll may be inserted under the palmar surface so placed that the fingers are semiflexed and the thumb abducted in a lateral and volar direction so as to lie under the roll By this means a more or less satisfactory "position of function" is secured from the inception of the treatment. The thumb may be held in position by some simple device such as that shown in Fig 207

of the tissue is low and that such hands will not bear pressure such as can be borne by ordinary tissue In some even the lightest pressure will produce local necrosis, therefore all splinted hands should be examined daily and upon the appearance of the slightest mottling of the tissue the splint should be modified or removed Gentle constant traction or pressure should be the rule, rather than forcible measures. This may be secured by elastic bands, springs, or packing between the splints and the part whose position is to be corrected Forcible manipulation followed by the use of splints to hold the parts in the new position may at times be used, but is generally inadvisable since the reactive inflammation produces new adhesions and contractures The splints should be light, not cumbersome, they should be so constructed as to be easily removed and reapplied by the nurse or physiotherapist In our service the splints are generally made from aluminum, and what they lack in workman-like appearance they gain in their adaptation to the needs of the individual patient Such splints can be bent from day to day as the changing condition of the patient's hand demands All that is necessary in making such splints is sheet aluminum, rivets, rubber elastic or piano wire springs, piano felt, leather for straps, buckles, and the ordinary tools such as a file, hammer, heavy scissors, and punch The splint can then be cut into any shape desired, with extended arms bent to carry elastic or spring extension from the fingers or thumb as may be needed to meet the individual requirements

The conditions in which they are used may be divided into general groups for the sake of clearness in discussion as to method of construction of the splints (1) Contraction of the hand with the fingers overextended at the proximal phalanx and the distal and middle phalanges flexed, (2) contraction with the fingers held extended in the normal relation, (3) contraction with the phalanges

the early stages of treatment to maintaining this "position of function" much less would be heard of disability after hand infections If the hand is kept in the "position of function" even though only a minimum of motion of the fingers and thumb is retained the patient will still have a useful hand for gross purposes The importance of this procedure cannot be overestimated

If a finger alone is involved and it is evident that the tendon will be lost or ankylosis of joints follow, the finger should be flexed about 30 degrees at the metacarpo-phalangeal and interphalangeal joints and held in this position by a splint (Fig 207) This degree of flexion is slightly less than the "position of function" but the subsequent contraction of scar tissue will increase the flexion to the best position of function for the finger Even with loss of the tendon, voluntary flexion and extension at the metacarpo-phalangeal joint is seldom lost

THE APPLICATION OF SPRING OR ELASTIC TENSION SPLINTS

Treatment in the later stages consists essentially in the use of physiotherapy as described in the preceding chapter, supplemented by the use of various types of splints designed to bring the hand and fingers into the "position of function," stretch tendons and fibrosed muscles, and mobilize adhesions By these means many of the milder types can be almost entirely restored to function and the severe types can be benefited

Each case presents individual problems so that no single splint can be devised that will answer in all cases Certain principles, however, may be established and basic splints described While these splints are adapted to a majority of patients, modifications embodying the principles must be devised by the surgeon to meet atypical conditions. One should always remember that the vitality

the fingers or thumb and stretch the adhesions about the joints as may be indicated.

Four basic splints have gradually been developed in our work which have proved of great value in the carrying out of the principles mentioned.[1] These basic splints are modified to meet individual requirements All are light in weight, fairly rigid, and made of hard, flat aluminum, No 2SH, .081 inch in thickness. The first (Fig. 209) is designed to maintain the hand in the "position of function," *i e*, with the wrist dorsiflexed, the thumb

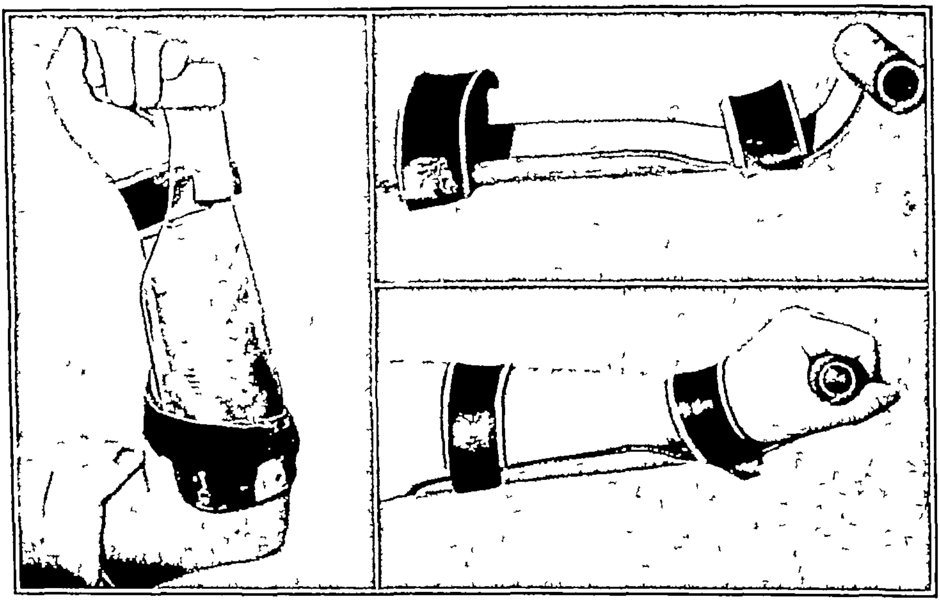


FIG 209 —Method of application of the simple volar splint

abducted from the hand and facing the fingers, and the fingers semiflexed, as though grasping a tennis ball. The splint is curved in its long axis so as to fit snugly to the volar surface of the forearm, it is slightly curved in a transverse axis just distal to the wrist so as to fit the "heel" of the hand Pressure on the thenar eminence is eliminated by the cutting out of a rounded portion on the radial side Dorsal flexion is regulated by the degree of flexion

[1] Lately we have succeeded in having these basic splints made according to our specifications by the American Metal Ware Company, 368 W Huron Street, Chicago

all flexed, (4) contraction with the thumb held at the side of the hand; (5) contraction with the hand volar flexed; and (6) fibrous ankylosis of any or all joints It is realized that any or all of these contractures may be present in an individual case, yet to overcome any one of these types of contraction certain principles in application of the splints should be observed, and it is the combination of these principles that builds up the splint applicable

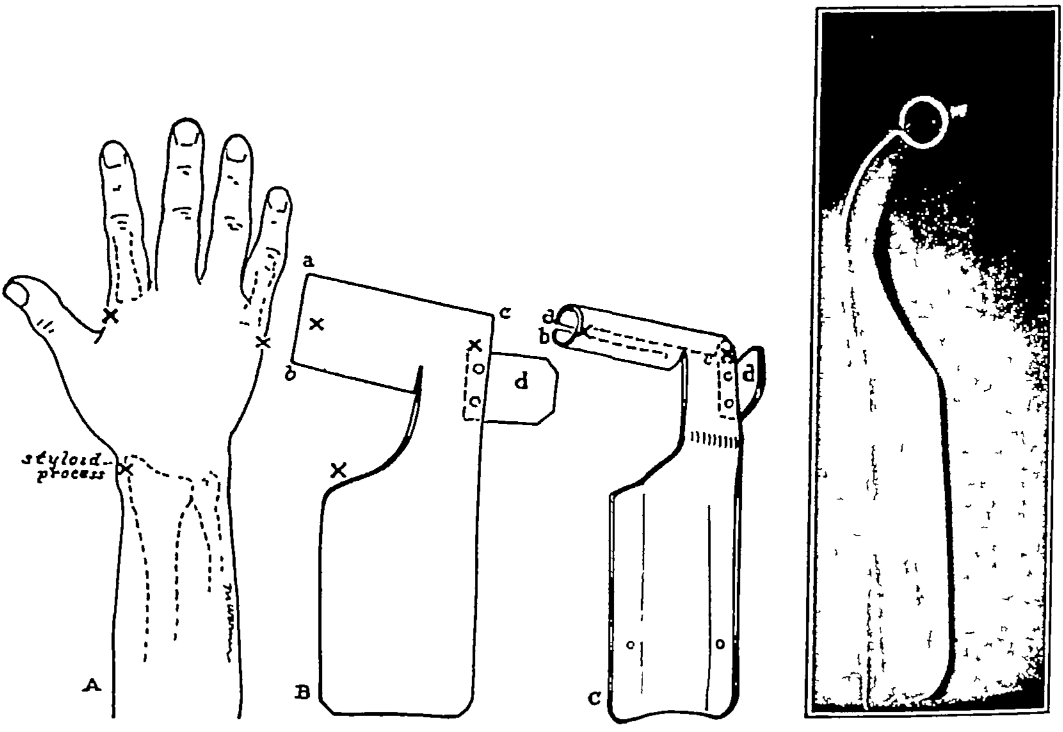


FIG 208 —Method of construction of the volar cock-up splint to hold the hand in the "position of function"

to the particular patient The line of attack should be intelligently directed toward bringing the hand and its members into the "position of function," stretching of adhesions, and mobilizing joints Therefore, we first attack the improper position at the wrist, and build our splint in such a manner as to produce dorsiflexion at the wrist On this basic splint we apply the arms to which are attached the springs or elastic that extend or flex

traction Arms may be added to hold the spring or elastic tension attached to the thumb or fingers

The second splint (Fig 211) is similar to the first, with the addition of a raised aluminum crosspiece attached to the volar surface of the splint at its proximal end to which straps with buckles, steel springs, and leather loops can be fastened for the production of elastic tension on the thumb and fingers Fig 211 shows the splint with straps for each finger. A sixth strap may be attached

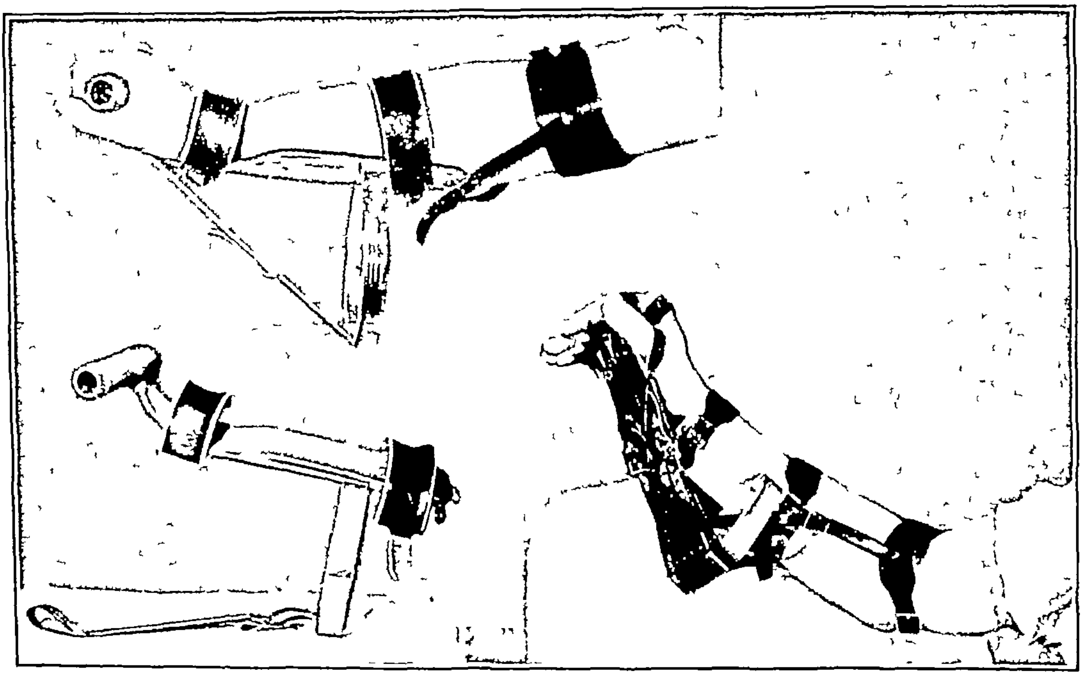


FIG 211 —Volar splint with various spring extensions and elbow cuff

to the loop over the thumb, to pull directly upward (in the line of the radius) and thus help to pull the thumb away from the hand into the abducted position, a consideration of particular importance if the thumb has been allowed to lie for days or weeks alongside the hand in the extended and prone position

The elbow cuff attached by straps and buckles to the upper corners of the splint helps to keep it from slipping down past the metacarpo-phalangeal joints when the pull on the fingers is increased

of the splint at the wrist The lower, rounded end of the splint separates the thumb from the fingers, but stops short of the metacarpo-phalangeal articulations so as to permit flexion of the fingers at these joints, the joints most often held immobilized after infection and injury, and as a result, most often involved in fibrous contractures

Such a splint can be padded with washable "feather edge" rubber, or with felt (Fig. 210) If the rubber pad is used the splint can be applied to the hand while infection is still present, as soon as it is possible to substitute

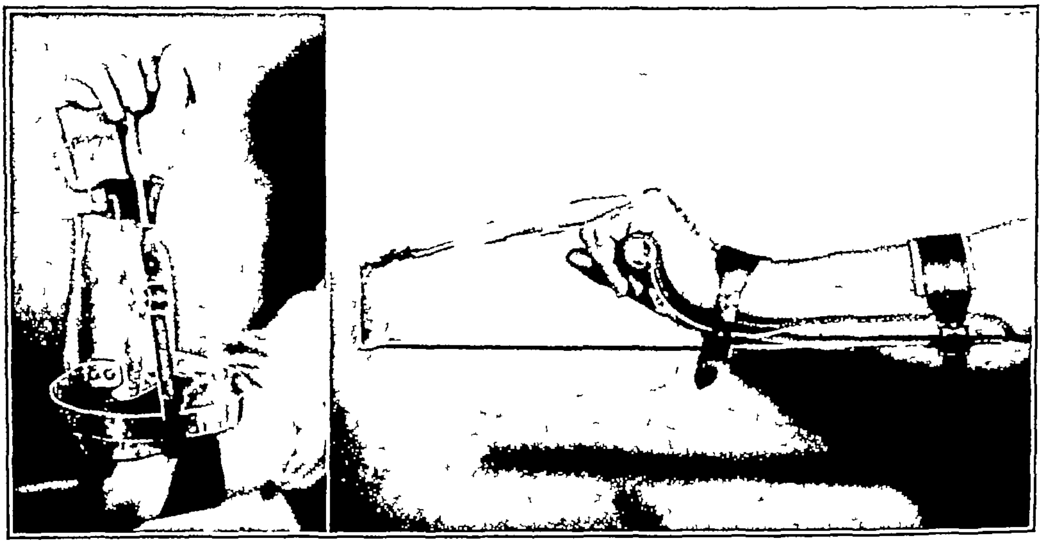


FIG 210 —Volar splint with spring extensions attached to produce flexion or extension of the fingers

intermittent hot, wet dressings for a continuous wet dressing—usually within four or five days of the onset of even a serious infection If padded straps with buckles are attached to the splint, it can be quickly taken off and reapplied—important factors if one is caring for a considerable number of patients or is treating patients who are not particularly interested in getting well quickly and therefore tend to neglect the treatment indicated. If lateral tension is applied to the thumb, a shoulder is added to the splint on the side to maintain counter

and hand It is designed, however, to aid in the extension of contracted fingers, and not, as in splints two and three, in the flexing of them Slotted extension pieces for each finger and for the thumb, if desired, are riveted to the hand-piece, and tension of any desired degree is applied to the flexed fingers with the aid of rubber or elastic loops and buckles. The arms are separated somewhat to pro-

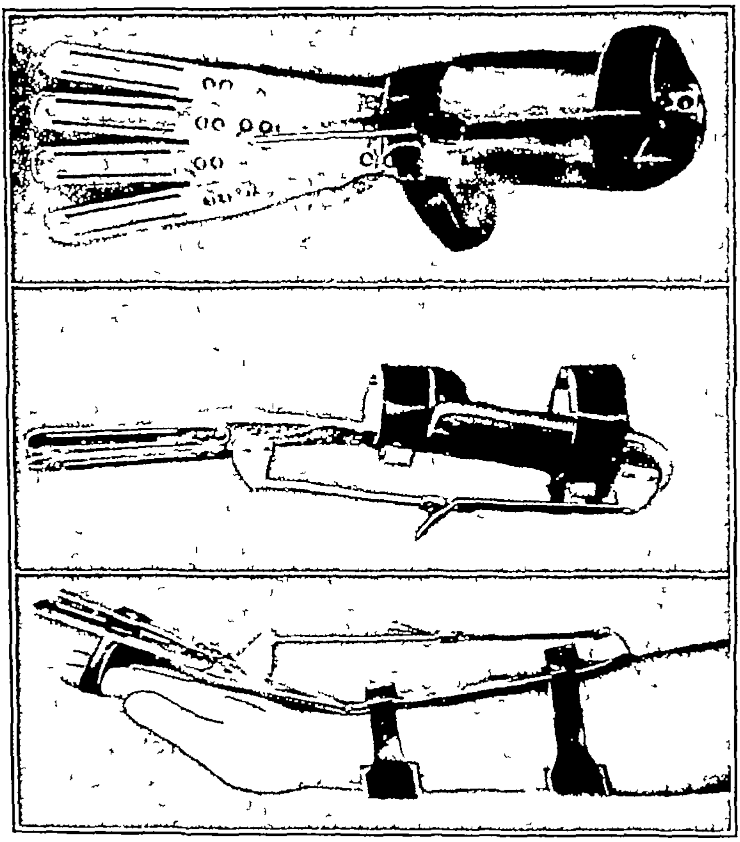


FIG 213 —Dorsal splint designed to produce extension of the wrist by spring traction and of the fingers by elastic tension

duce abduction as well as extension of the fingers This splint is helpful in the treatment of tendon contractures, and particularly in the treatment of that type known as von Volkmann's contracture In the latter condition it is frequently impossible to extend the sharply flexed fingers until volar flexion at the wrist relaxes the contracted tendons The hinge at the wrist in the splint

The third splint (Fig. 212) is designed to produce the same effect as the second, but is applied to the dorsum of the forearm and hand in cases in which the presence of wounds or operative incisions makes it desirable to avoid any pressure on the volar surface, or in cases in which involvement of the wrist-joint makes it desirable to bring elastic tension to bear on the periarticular structures of the wrist Dorsal flexion at the wrist is obtained with the aid of a hinge at the wrist, and a backward pull on the hand secured with the aid of a strong spring on the

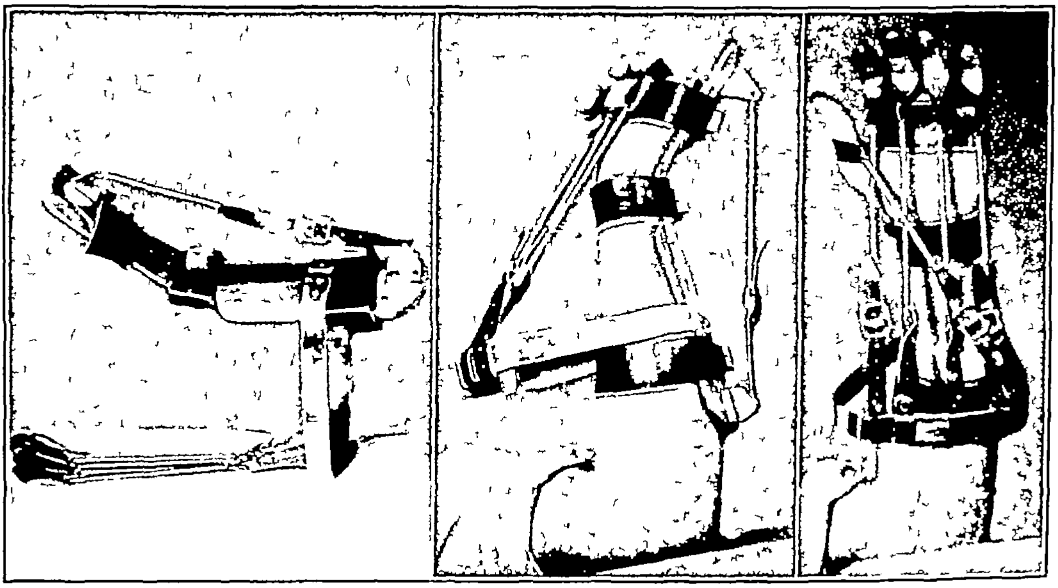


FIG 212 —Dorsal splint designed to produce by spring traction extension of the wrist and flexion of the fingers

back of the splint The effect produced on the fingers and thumb is exactly the same as with the second splint The elbow cuff to prevent the splint from slipping distalward, shown in Fig 211 is attached in the same fashion to splint three, but has been omitted in the illustration shown Pressure on the styloid process of the ulna is eliminated by cutting out a rounded portion of the splint on the ulnar side just above the hinge

The fourth splint (Fig 213), like the third, is hinged at the wrist and is applied to the dorsum of the forearm

as to pull in the line of the forearm instead of dorsalward. Here the U-shaped arm can be attached to the volar splint passing some 2 inches beyond the ends of the fingers, or we may use a dorsal splint and attach arms going over each of the fingers out to and beyond the end of the fingers for some 3 inches and bent at the ends so that the same line of tension can be secured We may use springs or elastic tension attached to each finger by gauze and Sinclair glue as already described It should be empha-

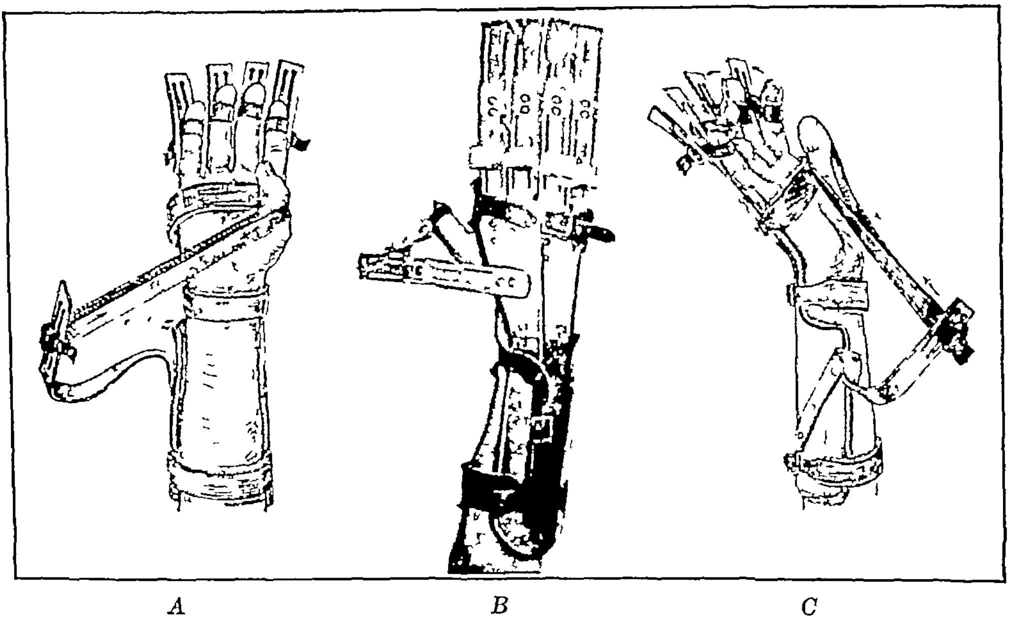


FIG 214 —Various types of extra arms so attached as to produce extension or flexion of the thumb and extension of the fingers In (*B*) a spring extension is used to produce extension of the hand at the wrist

sized that the necessity for the line of tension in the direction of the forearm is necessary not only because of the position of the middle and distal phalanges which make this position of attachment necessary for advantageous pull, but also it is necessary because of the fact that if the tension pulls dorsalward there is a tendency to overextend the proximal phalanges, tending to produce paresis of the lumbricals and interossei.

Where the thumb is not in the "position of function" and the malposition of the thumb permits it we may

illustrated permits volar flexion, of any desired degree, at the wrist. As the contracted tendons are gradually stretched, one is able to straighten out the wrist and maintain tension of any desired degree by tightening the strap on the back of the splint, and, if necessary, increasing the strength of the springs or adding a second spring.

While these four splints will meet the requirements in most cases the surgeon must modify them to meet special conditions or add other arms if necessary The strap slings may be placed about the proximal or middle phalanges as the condition demands

Where we have much difficulty with the distal phalanx we frequently attach the spring by means of gauze and Sinclair glue to the distal phalanx A simple method of producing flexion of the fingers is to place a glove on the hand, to the dorsum of the fingers of this glove straps are sewed which may be buckled to springs attached at the wrist This permits fairly satisfactory flexion of all the phalanges in simple cases, but is inadequate in severe contractures since the wrist is not fixed We sometimes use it in the terminal stages of the treatment.

Where there is overextension at the proximal phalanx with moderate extension of the second and third phalanges we may be able to overcome the hyperextension by the application of the basic splint but with the attached bar brought still farther distalward on the splint, gradually moving it back as we bring the proximal phalanx into flexion Where we have this overextension, however, it is not uncommon for us to find the adhesions so firm about the metacarpo-phalangeal joint that the spring tension just described will not be sufficient to bring the phalanx into flexion In these cases operations on the ligaments about the joint must be resorted to with subsequent splinting

If the distal and middle phalanges are flexed and the proximal extended, the extension must be so attached

CHAPTER XXX

OPERATIVE TREATMENT FOR SEQUELÆ OF INFECTIONS.

WHEN one considers the wholesale destruction of tendons, atrophy and fibrosis of muscles, destruction or compression of nerves, fibrous or osseous ankylosis of joints, immobility of the thumb, overextension of the proximal phalanges, atrophy and loss of nutrition in the skin seen in the ultimate stage of neglected ulnar and radial bursal infections, it is realized that the surgical procedures entailed in their correction must call for the highest degree of surgical skill While many of the simpler conditions are amenable to ordinary surgical technique, these severe sequelæ of tendon-sheath infections demand complicated surgical procedures such as tendon transplants, nerve surgery, arthroplasties, and lateral ligament operations. To enter into an adequate description of all of these procedures would demand a consideration of almost the entire field of plastic surgery of the hand. This would not come within the limits of a contribution confined to a consideration of infections of the hand It has seemed wise, therefore, to reserve a complete discussion of this subject for another time and place. A brief discussion, however, of the simpler procedures and an outline of the basis of the reconstructive surgery in the graver lesions with a suggestion as to what may be accomplished will enable the surgeon to choose between radical procedures, such as amputations, and conservative measures when confronted with grave complications, and to treat his patient in such a manner as to make these later reparative procedures more satisfactory It is also

attach elastic or spring tension to the basic splint In some cases, however, it will be necessary to rivet an arm onto the aluminum splint; as shown in Fig. 214, this arm is attached and bent and extends out 5 or 6 inches from the splint, sometimes on the radial side, sometimes on the ulnar side, as the malposition of the thumb may indicate Our desire is, first, to place the arm in such a position that when the tension is exerted it will tend to pull the thumb away from the palm, thus stretching the adhesions that may be present holding the thumb in the malposition, and to bring the thumb ultimately into the "position of function" with the flexor surface of the thumb opposite the flexor surface of the index finger, and, secondly, to produce mobility in the thumb It is evident, therefore, that it may be necessary to apply an arm in such a manner as to first produce radial abduction of the thumb and then after the stretching has occurred to place the splints on the ulnar side so as to draw the thumb away from the palm and toward the ulnar side

To summarize, therefore, aluminum splints are fitted to the forearm either on the flexor or dorsal surface and so constructed as to produce the cock-up position and mobility in the wrist-joint To these forearm splints, arms are attached pointing in various directions and these are attached to the digits with springs or elastic intervening so that the line of traction will tend to produce mobility in the joints, bring the digits into the "position of function" and stretch the adhesions in such a manner as to permit free motion It is evident that each patient presents an individual problem that stimulates the imagination of the surgeon and sustains his interest.

If there is no other disability so that the patient is enabled to use the fingers actively the result is often excellent Where, however, he cannot move the fingers freely the result is impaired by recurring adhesions

It is proper at this point to discuss the principle of free fat transplants. That they will to a considerable degree be absorbed cannot be gainsaid but, on the other hand, some small part does remain, moreover if physiotherapy is used persistently it has seemed to me that a greater mobility is secured by the primary insertion of the fat than by mere dissection followed by physiotherapy. It should be emphasized that fat transplant without physiotherapy is of little value and it should also be emphasized that wherever living fat on pedicles can be secured it should be used in preference to free transplants

Where we have mid-palmar adhesions without an inflammation of the tendon sheaths a like good result generally can be promised Here, however, the tendons, lumbrical muscles, the nerves, and the bloodvessels, must be dissected out from the scar tissue with the greatest of patience, and flaps of fat from some other portion of the body transplanted both above and below the tendons Especial care should be exercised to dissect out the lumbrical muscles In fastening these flaps of fat about the muscles and about the nerves and bloodvessels, the finest obtainable catgut or silk is used and as few sutures as possible placed

Where the index, middle, or ring finger tendon sheath has been involved with resulting deformity and disability, the operative procedures will vary with the degree of disability and the social status of the individual If a working man, it is probable that he will have neither time nor necessity for the prolonged plastic procedures necessary to secure motion in the distal joints In such cases this disability should be anticipated and the finger fixed during treatment so that ankylosis will have taken place

of much comfort to the patient confronted with the functional loss of his hand to be assured that some improvement, whether small or great, can be assured by subsequent reconstructive surgery. All open operations should be delayed until at least six months after all evidences of infection have subsided.

The reparative procedures following felons of the distal phalanx have been touched upon when dealing with that subject. The excision of simple scars preventing mobility of the fingers needs no discussion Adhesions about tendons on the dorsum and in the palm outside the tendon sheaths may require surgical attention In such cases every endeavor should be made by physiotherapy to develop a functioning hand If this fails, I have never seen violent tearing of the adhesions under anesthesia give permanent good results In such cases our practice is to make an open incision, dissect out the scar tissue, and in most cases transplant fat or living tissue around them On the dorsum a curved longitudinal incision is made in the median line The value of the curve lies in the fact that if the scar contracts there will be less binding of the tissues The tendons are now dissected from the skin and the underlying bone We generally do not attempt to separate the tendons from each other except between the index and middle fingers The three ulnar fingers work together satisfactorily and what independent action they have is not impaired unless there has been an exceptional destruction and subsequent fusion. Through the opening between the index and middle finger tendons the separation of the tendons from the metacarpals is easily secured A sheet of fatty tissue is now taken from some other part of the body and placed under the tendons It is generally not necessary to place any superficial to the tendons The wound is closed and immobilized in the "position of function" for a week, after which time active and passive motion is begun.

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with the phalanges flexed on each other at an angle of 45 degrees, a position entailing little disability. If, however, this has not been done and the finger is ankylosed in a straight position the patient often complains of disability due to the fact that the extended finger strikes objects when the other fingers are flexed In such cases the two distal joints may be resected and reankylosed in

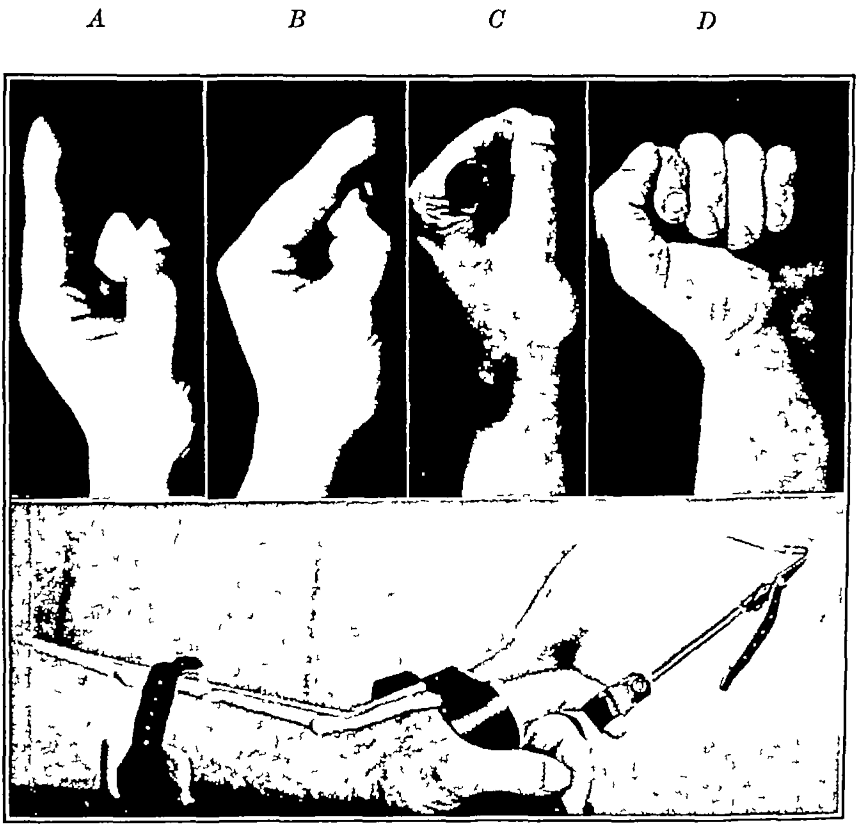


FIG 215 —Loss of index tendons (*A* and *B*) Tendon transplant with result (*C* and *D*) The lower picture shows an extension spring attachment used after the transplantation, during the period of physiotherapy

the more favorable position Amputation is seldom called for

If the patient is young, desires a functioning finger, and is willing to spend the necessary time, in most cases a greater or less degree of mobility of the phalanges varying with the pathology present may be secured by a tendon transplant (Fig 215) Where the incision for

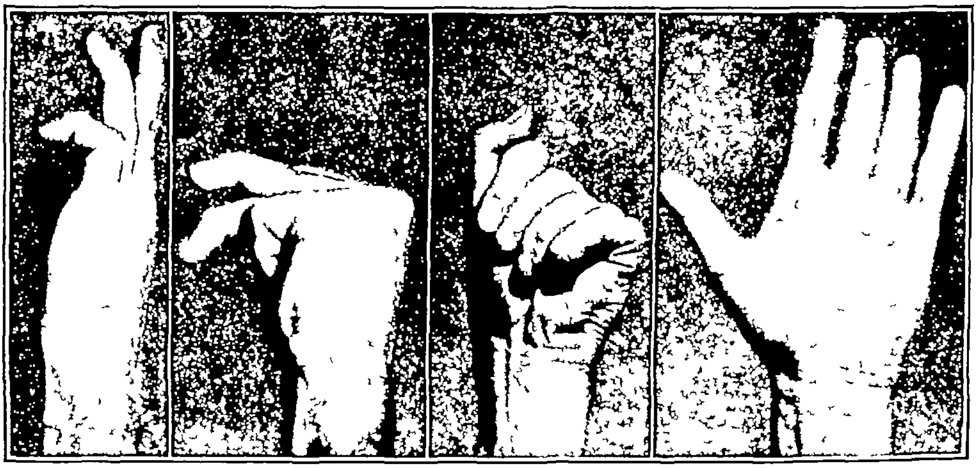
drainage has been made laterally, and there is no ankylosis of the joints or loss of skin and the finger is not too atrophic, the results of such operations are very satisfactory. If, however, these complications are present the operative procedures may include arthroplasty and transplantation of skin. This we have done at times with marked success, but we do not approach such cases with the same assurance as we do the simpler type. The skin transplant may be either a free or pedicled graft. In favor of the former is the simplicity of the procedure and in favor of the latter is the fact that the graft will have fat attached that favors the ultimate free movement of the tendon that is inserted at a subsequent operation. If arthroplasty is necessary, a free resection of the joint or joints is made and tags of surrounding tissue or free grafts of fat inserted We have generally been content to attempt only to procure mobility in the middle interphalangeal joint, leaving the distal joint ankylosed The metacarpo-phalangeal joint is seldom fixed In these cases the arthroplasty is performed at the same time that the tendon is transplanted. A fair degree only of function can be promised, it is sufficient, however, to lessen materially the disability and improves markedly the cosmetic result

The tendon transplant is generally taken from the extensor tendons of the small toes of the foot. We have, however, used silk braided through fragments of the partially destroyed tendon with good results In the latter instance the plastic procedure is supplemented by a free fat transplant

When we are confronted with the disastrous sequelæ already described as accompanying neglected ulnar and radial bursal infections the plastic procedures are necessarily multiple and complicated No two cases present the same problems To meet these often multiple operations are necessary While each of the conditions to be dis-

cussed is not separately attacked yet it simplifies the presentation to consider them individually (Fig 216).

Before resorting to any operative procedure the patient should receive purposeful physiotherapy In the first place we desire to secure as much improvement as possible in function, but of equal importance in view of ultimate operative procedures is our endeavor to stretch the ligaments about the joints and develop the muscles so that after the surgical removal of adhesions and restoration of tendons the patient may begin to move the parts by voluntary action. It is somewhat difficult to convince



A *B* *C* *D*

FIG 216 —Tenolysis and tendon transplant for impaired function of middle, ring, and little fingers *C* and *D* show the final result

a patient that he is developing a muscle by active attempts at contraction when he does not see some motion of the digit. Nevertheless this is one of the most efficient means of developing a muscle preliminary to operation The hot and cold douches and other physiotherapeutic procedures also increase the nutrition of the skin and other tissues.

The general purpose of our operative procedures is to bring the hand into the "position of function" and obtain to the greatest degree possible mobility of the parts and function of muscles. The degree possible

naturally depends upon the amount of destruction and involvement of the various structures In almost all cases, even the most desperate, we are able at least to bring the hand into the "position of function" and restore sufficient motion to permit the patient to carry out gross functions such as holding tools, using a knife and fork, driving an automobile, etc. In the less serious cases a high degree of function can be secured

It may be necessary as a preliminary procedure to transplant skin to the flexor surface of the wrist. This is done in those cases where the skin and tissues at the wrist are atrophic and contracted It is necessary since if much reparative work is done on the tendons and particularly if pedicled or free transplants of fat or other tissue are used, there will be difficulty in closing the wound unless added skin is avilable. The same is at times necessary on the flexor surface of the fingers

The destruction of the tendons at the wrist with the fusion of the remnants into one undifferentiated mass bound in a mass of adhesions to the tissues of the carpal canal and the anterior annular ligament has been mentioned. In these cases it is necessary to make an incision extending from the lower fourth of the forearm across and through the transverse carpal ligament The median nerve is then identified in the forearm and followed down into the palm, being careful not to cut the motor branch to the thenar muscles At times the nerve is completely destroyed The intact tendons, if any, are then dissected out At times we must be content to differentiate only two groups, superficial and deep, not separating these into their respective tendons In other instances we have been able to transplant tendons where individual tendons only were lost These tendons or groups having been separated we envelope them in pedicled flaps of subcutaneous tissue with fat obtained from adjacent areas If these cannot be obtained we transplant free

grafts of fat from other parts of the body, preferably the elbow region of the arm, placing the fat below the deep flexors, and between the deep and superficial being careful to segregate the median nerve At times the ulnar nerve or its divisions may be involved and if so should be freed In the closure no attempt is made to suture the transverse carpal ligament

The incision may be extended into the palm for a sufficient distance to permit dissection of the palmar tendons and the terminal divisions of the ulnar and median nerves followed, if necessary, by protective transplants of fatty tissue.

Not uncommonly even though tendons are not transplanted to replace all those lost at the wrist, it may be necessary to transplant a tendon to replace that of the little finger or others that may be necessary to function.

In these severe lesions it is almost always necessary to institute operative procedures to permit flexion of the overextended and partially ankylosed proximal phalanx Here the lesion is not simple In addition to the pathology present about the metacarpo-phalangeal joint we have also fibrosis of the lumbrical and interosseus muscles with scar tissue binding the digital nerves in the lumbrical canal. This calls for the freeing of these muscles and nerves preceded and followed by physiotherapy to develop the muscles. The fixed overextension is corrected by detaching the lateral insertion of the joint ligaments through dorsal incisions and bringing the fingers into marked flexion. If bony ankylosis is present, a resection of the joint may be indicated

In many cases we find bony ankylosis of the wrist-joint often with no differentiation of bones In such instances we resect the joint removing the remnants of all the carpal bones The radial surface of the new joint is made concave and the distal convex. Into this cavity is inserted a free transplant of fat, filling it completely

The procedures necessary to bring the thumb volarward and rotate it so as to bring it into the "position of function" are variable and complicated. This reconstruction, however, is absolutely necessary if we are to obtain a result anywhere near satisfactory. While motion is important, if it can be obtained, the position described is paramount since if this is present, the radial fingers, even with slight motion, can be brought into opposition with the thumb and many necessary functions performed If the thumb is fixed at the side of the hand, it may be necessary to cut the adductor transversus and part of the opponens This may be supplemented by plastic operations upon the tendons attached to the thumb and in extreme cases resection of the carpo-metacarpal joint may be advisable In case of necessity I would not hesitate to ankylose the thumb in the "position of functions"

These various operations including treatment of the adhesions on the dorsum are performed in two to three stages giving sufficient time between the various operations for complete healing During the intervals physiotherapy is continued and tension splints applied to maintain what has been gained and draw the hand and fingers still farther into the "position of function" It is manifest that these procedures will consume many months, but the effort is worth while when we remember that the hand was absolutely worthless The patients are always well satisfied and grateful even though the result may fall short of what we as surgeons would desire In many instances the function obtained has surpassed our expectation

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